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ODHAMS PRACTICAL AND TECHNICAL ENCYCLOPÆDIA

Covering terms used in

MECHANICAL ENGINEERING · AUTOMOBILE ENGINEERING
ELECTRICAL ENGINEERING · AERONAUTICAL ENGINEERING
BUILDING · PAINTING AND DECORATING · PLUMBING
CARPENTRY AND JOINERY · CHEMISTRY AND PHYSICS
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HOW TO USE THIS BOOK

THIS encyclopædia has been compiled in the simplest possible way for quick reference, and entries are in strictly alphabetical order irrespective of whether or not two or more words form a term. For example, *F-Layer* will be found to follow *Flask*, because its fourth letter, *y*, is later in the alphabet than the fourth letter, *s*, of *Flask*. Similarly, *Acetic Acid* comes after *A.C.—D.C. Receiver*, but before *A.C. Generator*.

The use of abbreviations has been kept to a minimum throughout and, in general, only the well-known ones have been employed, such as:—

c.c.	=	cubic centimetre(s)	**in.**	=	inch(es)
cm.	=	centimetre(s)	**lb.**	=	pound(s)
cu.	=	cubic (inch, foot, etc.)	**m.**	=	metre(s)
deg. C.	=	degrees Centigrade	**mm.**	=	millimetre(s)
deg. F.	=	degrees Fahrenheit	**q.v.**	=	which see
ft.	=	foot (feet)	**sq.**	=	square (inch, foot etc.)

However, there are some abbreviations of technical terms that are so widely used that they have themselves become accepted terms. *E.M.F.* and *H.T.* in electrical engineering and radio, and *O.H.V.* and *T.D.C.* as applied to internal-combustion engines are instances.

Subject identification is not given to every term as, in the majority of cases, to do so would be a waste of valuable space. The classification of many is at once self-evident. Others are immediately identified by the opening words of the text thus, "*Athodyd—a jet-propulsion engine for aircraft* . . . ". When a term has applications in different specific subjects, its classification is prominently given thus, "*Ball Valve* (*Mech. Engineering*)" and "*Ball Valve* (*Plumbing*)". If a term is employed more or less generally, as is *Baffle*, it cannot be classified; but if it also appears again in connexion with another of the subjects covered by the encyclopædia, then it is classified thus, "*Baffle* (*Radio*)".

The whole of the text was specially written for this book and no part of it has previously appeared elsewhere. To ensure the highest degree of accuracy, every word was scrutinized in manuscript form by independent advisory experts, even though all the contributors are highly qualified specialists. In the later stages of production, the proofs were read by further experts.

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ABRASIVES. Natural or artificial materials used in various forms for grinding purposes, either to produce smooth surfaces or, in engineering, for the actual shaping of metal and other materials. Corundum, emery and diamond, on account of their hardness, form the main natural abrasives. Artificial abrasives are divided into two chief classes: aluminous (alundum and aloxite) and silicon carbide (carborundum). They are manufactured respectively from bauxite, and from glass or silica sand combined chemically with carbon derived from coke. All abrasives are normally graded by screens, or sieves, of various standard meshes, the classification depending upon the proportion of residue which will not pass through the standard sieve.

Selection of abrasives for grinding wheels depends upon the nature of the materials to be ground. Generally aluminous abrasives give best results with materials of high tensile strength; silicon carbide abrasives are more successful with those of lower tensile strength. Hardness and ductility, however, also influence the selection of the abrasive.

In painting, the function of abrasives is to remove all foreign matter which might form an unstable foundation for superimposed finishes, and to leave a clean, slightly granulated plane surface. Stone surfaces are rubbed with a block of stone of similar texture, brickwork with a brick of the same type. Iron work is "sand-blasted", a stream of dry sand under pressure being directed against the surface. Where this is not possible, rust and scale are removed with hammer, file, and wire brush. The normal abrasive for cutting-down old paint work is pumice stone, either natural lava of selected grades in lump form, or the pulverized stone recast into conveniently sized blocks, the lubricant being a weak solution of soda and water. Emery, carborundum, garnet, flint, sand, and glass cloths and papers are the most convenient form of abrasive for general purposes. These may be obtained with the fixative either waterproof or otherwise. Their texture varies widely, its coarseness being indicated by progressive numbers from the normal 0 or fine; groups of ciphers (00,000 etc.) indicate extreme fineness. These latter are generally known as felting papers. Ground pumice stone, finely powdered, is used for cutting-down varnished surfaces before revarnishing, with clean water as the lubricant.

Finer abrasive powders such as rouge, Tripoli powder and putty powder lubricated with linseed oil are used for re-establishing the polish without revarnishing. See DIAMOND TOOLS.

ABSOLUTE CEILING, see CEILING.

ABSOLUTE TEMPERATURE. Temperature measured on a scale the zero of which is $-273{\cdot}1$ deg. C. On this scale, sometimes called the Kelvin scale, one degree is equivalent to 1 deg. C.

At the zero mark on the absolute temperature scale, the atoms or molecules of a gas would have no movement, assuming that at such a temperature gases obey the laws they obey at known temperatures. As the volume of a gas at constant pressure is proportional to the absolute temperature, at the absolute zero a gas would have no volume, and the absolute zero would seem to be one that is impossible to attain. See GAS LAWS.

ABSORPTION DRYING (Printing). The kind of drying which takes place when printing ink is absorbed by the

unsized or soft-sized stock (paper). Newspapers are a typical example. See PRINTING INKS.

ABSTRACTING, see BILL OF QUANTITIES.

A.C., ALTERNATING CURRENT (q.v.).

ACCELERATION. The rate of change in the velocity of a body, usually expressed in centimetres per second per second, or feet per second per second. In London the acceleration due to gravity of a falling body in a vacuum is 32·19 ft. per second per second, but it varies slightly from place to place.

Acceleration may sometimes be more conveniently measured as: miles per hour per second; kilometres per hour per second; metres per second per second etc. In order to reduce wear and tear on the transmission mechanism and tyres of road vehicles, acceleration along the road must take place gradually and smoothly; the factors making for this, when starting from rest, are the rapid response of the engine as the throttle is opened and the good condition and gradual engagement of the clutch.

ACCELERATOR. Any piece of mechanism in engineering which serves to increase the speed of a moving body, fluid or gas; any chemical which increases the speed of a chemical action; or, a type of electrode in a radio valve.

In motor vehicles the accelerator usually consists of a foot-operated pedal connected, by a system of rods and levers, to the throttle valve of the carburettor, which it controls. On many vehicles supplementary mechanism is provided to prevent the engine speed falling below a predetermined limit when the accelerator pedal is released or to prevent, by means of a governor, a certain high limit when it is depressed. Another accelerator, of the type first mentioned above, is the pump used in central-heating circuits to increase the rate of flow.

Most modern internal-combustion engine carburettors incorporate a form of special accelerator pump to supply extra fuel during acceleration.

ACCEPTOR CIRCUIT. A tuned circuit consisting essentially of a coil and a condenser *in series*. At resonance, the reactive components of the

Diagram of a simple acceptor circuit comprising a coil and condenser connected in series.

impedance cancel out and, in the absence of resistance or other losses, the impedance is then zero. So called because it "accepts", or offers the least opposition to, current of the frequency at which it resonates. See TUNING.

ACCESSORY GEARBOX. A gearbox incorporated in modern aircraft design for driving accessories, such as the vacuum pump for gyroscopic instruments, hydraulic pump for operating flaps, undercarriage, gun turrets etc., and the dynamo for supplying electrical power.

Formerly, the engine manufacturer provided drives for the accessories at various points on the engine, such as the ends of camshafts. It is now becoming common practice to group all the accessories of an engine on an accessory gearbox which can be placed in any position the aircraft manufacturer finds desirable.

In this case only one driving point on the engine is then required, and the power is taken to the gearbox through a rigid or flexible shaft.

ACCUMULATOR. An electrochemical device in which a reversible action occurs. During charging, electrical energy is converted into chemical energy and stored in that form, while the reverse process occurs during discharge. Two or more accumulator cells connected together constitute a battery. Synonyms: Secondary Cell, Storage Battery. See LEAD-ACID ACCUMULATOR and NICKEL-IRON CELL.

A.C.-D.C. RECEIVER. A radio receiver which will operate from either alternating-current or direct-current mains without alteration or adjustment being necessary. It is sometimes called a *universal* receiver.

ACETIC ACID ($CH_3 \cdot COOH$). A liquid obtained in the impure form of vinegar by the fermentation of vegetable matter. In decorating work, a weak solution is often applied to plastered surfaces to correct excessive alkalinity before distempering, paper-hanging or painting. Acetic acid is also used as a wash to neutralize the caustic action of soda upon superimposed paint films when the old painted surface has been removed with materials containing soda and lime, or when the old paint has been cut-down with pumice stone and a lubricant containing either of these materials.

ACETYLENE. A colourless, explosive gas, density relative to air: 0·91 consisting of a chemical combination of carbon and hydrogen and having the formula C_2H_2. It is formed when water is allowed to come into contact with carbide of calcium. Industrially, its most important application is in conjunction with the use of oxygen for welding and cutting metals. With the oxy-acetylene flame—which is much hotter than that produced by an oxy-hydrogen jet—metal up to 36 in. thick may be cut; moreover, the cutting can be carried out under water.

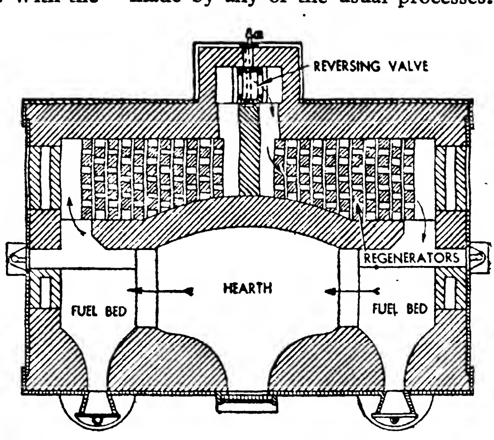
In the autogenous welding of metals acetylene and oxygen are made to mix in a blowpipe, or torch, so designed that perfect combustion takes place at the tip. Owing to the risk of explosion, acetylene gas must not be stored as a compressed gas in cylinders; but it is readily soluble in several liquids, and may thus be safely stored in solution. The liquid most generally employed for this purpose is acetone. Acetylene is also used in the production of acetic acid, alcohol, isoprene and artificial rubber. See AUTOGENOUS WELDING.

A.C. GENERATOR. An electrical machine which, when driven by a steam engine or other prime mover, generates alternating current. See ALTERNATOR.

ACID. A compound containing one or more atoms of hydrogen that are easily replaced by a metal, such as sodium, copper or zinc. Acids are practically all soluble in water, have a sharp taste, and turn litmus paper red; many of them dissolve or corrode metals. There are very many organic acids containing the group $-COOH$ or several such groups.

Other organic acids, called the sulphonic acids, contain the group $-SO_3H$ instead of the group $-COOH$. Carbolic acid, C_6H_5OH, and picric acid, $C_6H_2(NO_2)_3 \cdot OH$, contain neither $-COOH$ nor $-SO_3H$ groups. They do, however, have some of the properties of acids.

ACID STEEL. Steel made by refining pig iron, or a mixture of pig iron and steel scrap, under a siliceous slag in a furnace having an acid bottom and lining. Acid steel may be made by any of the usual processes.



Acid steel is produced in large quantities in furnaces which operate on the principle of Siemens' first furnace, with regenerators as shown.

Carbon, silicon and manganese are removed, but sulphur and phosphorus are not eliminated, consequently the proportions of these elements present in the charge must be restricted to low values, or satisfactory steel will not be obtained. Acid steel generally contains less non-metallic inclusions than

basic steel and, consequently, is often specified for important duties.

ACORN VALVE. A type of radio valve about the size and shape of an acorn and designed for use at very high radio frequencies. The small size of the electrodes and the shortness of the lead-out wires give an important reduction in inter-electrode capacities. Contact pins are not fitted; the lead-out wires, which are attached to small clips, form both the contacts and the mounting.

ACOUSTIC FEED-BACK. A condition which may cause oscillation, generally at audio frequency, when sound waves from a loud-speaker—particularly of a public address amplifier equipment—strike a microphone or, in some other way, set up voltages which are fed back to the amplifier. Amplification of these voltages causes a louder sound from the loud-speaker and this in turn produces a yet larger input to the amplifier. A vicious circle is thus started and almost instantly the system builds up into sustained oscillation.

ACOUSTICS. The science of sound and sound-wave propagation in gases, fluids and solids. Sound-waves can be reflected and absorbed, and have both velocity and frequency. Frequency determines the pitch, but has nothing to do with the velocity, which is governed by, and varies considerably with, the medium in which the wave travels. In air, for example, sound travels roughly at the rate of 1 mile in 5 secs., whereas in iron—along an iron bar or railings—its speed is nearly 15 times as great. The frequency of a vibration is doubled for every octave through which the pitch is raised: a middle C on the piano equals 256 vibrations per sec.; higher C equals 512 vibrations per sec. and so on. In addition to the above "fundamental" vibrations, there is with each note a number of harmonic vibrations. It is the pattern of these which gives a tone a characteristic timbre and distinguishes, for example, a "middle C" on a piano from a "middle C" on an organ. Sound-proof construction of walls and buildings is based on the absorption factor of certain materials, natural or artificial. Thicker walls of any given material absorb more sound than thin walls, but soft materials such as wool, seaweed and felt are sound-deadening even in thin layers.

A.C. RECEIVER. A radio receiver which derives its power supply entirely from alternating-current supply mains. See RADIO RECEIVER.

ACTINIUM (Ac.). Atomic no. 89; atomic weight 227; a radio-active element formed from protoactinium by the loss of an α particle. It readily decomposes, forming radioactinium. Other elements of this series are actinium A, B, C etc. It is trivalent.

ACTIVATED CARBON. A substance made from charcoal, especially the charcoal from coconut shells, by heating it so as to drive off moisture and open the capillary tubes; it may also be made by so heating some varieties of coal under carefully defined conditions. Activated carbon is used in gas-masks for absorbing poison gases, and in industry for absorbing valuable vapours such as benzene and toluene from town gas, or from the air of a factory where such substances are in use; it is also used for decolorizing liquors in the sugar and other industries. When the activated carbon has absorbed, say, toluene, it gives up the toluene on being heated and may be used again.

ACTIVE COMPONENT. The component of an alternating electric current which is in phase with a voltage, usually the voltage producing it, or the component of the voltage which is in phase with the current, for example, the current in, and the voltage across, a load. When the two are multiplied, the result is power. Synonyms: In-phase Component, Wattful Component, Power Component. See POWER FACTOR.

ADAMANT. A type of hard wall plaster used for the skimming or finishing layer of a plastered surface. It is made by baking gypsum (calcium sulphate) and steeping it in a solution of either alum or borax. It is then rebaked and reduced to powder and

before use is mixed into a paste with water without the addition of lime putty. After application to the surface it may be satisfactorily primed with oil paint as soon as the surface will stand the pressure of the brush applying the paint. Adamant is also used for making-good cracks and faulty portions in old plastered surfaces, the fracture being raked out, dusted and painted with oil paint before and after filling. All surfaces should be finished in this type of material if painting in oil paint has to follow the plastering immediately.

ADCOCK ANTENNA. A type of aerial often used at fixed direction-finding stations and evolved by Adcock in the period 1914 to 1918 to reduce *night effect*. It behaves like a loop aerial with the upper horizontal limb removed and the lower one completely screened.

ADDENDUM, see SPUR GEAR.

ADHERENCE. The ability of a substance to grip on to another. In enamelling processes the term adherence may be used in describing the bond of a cover coat of enamel, but this is exceptional, most enamellers using the word in connexion with the ground coat only. Several methods of measuring the degree of adherence have been evolved.

ADIABATIC. A change in the pressure and volume of a mass of gas in which no heat is taken from or given up to surrounding bodies. The gas experiences a change in temperature, the external work done during compression appearing in the form of heat. The most common example of adiabatic compression occurs when a bicycle pump is operated quickly; the pump gets very warm.

The compression of gas which takes place in the supercharger of an aero-engine approximately follows the adiabatic law.

ADJACENT-CHANNEL INTERFERENCE, see INTERFERENCE.

ADMITTANCE. The reciprocal of impedance, usually expressed in mhos.

$$\text{Admittance (mhos)} = \frac{1}{\text{Impedance (ohms)}}$$

AERIAL. A conductor or system of conductors elevated above the ground, and in general, insulated from it.

All aerial systems have tuning properties in almost exactly the same way as do the tuning circuits of transmitters and receivers; in fact, the only real difference is one of physical size. Simple aerials may be divided into three main classes, the *Marconi*, the *Hertz*, and the *loop* or *frame* aerial, the last being suitable for reception only.

The Marconi aerial consists essentially of a wire of indefinite length tuned to the required wavelength by means of a coil placed in series with it. This coil, which provides the means of coupling the aerial proper to the transmitter or receiver, may be either series or parallel tuned, depending upon the relationship between the physical dimensions of the system and the wavelength concerned (Fig. 1).

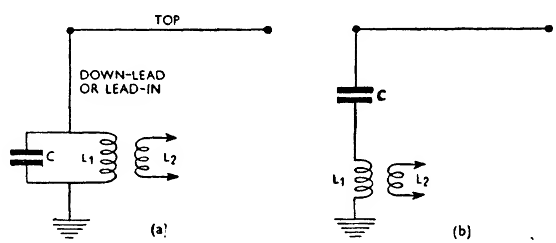


Fig. 1. Marconi aerials showing tuning arrangements. Method (a) is used when the combined lengths of top and lead-in are less than a quarter wavelength and that shown at (b) is used when the length is greater than a quarter wavelength. In both sketches L_1 and C are the tuning components, while L_2 provides a convenient means of making appropriate connexion to the receiver.

The Hertz aerial or *dipole* operates on the principle that its natural wavelength, i.e. the wavelength at which it oscillates freely, depends upon its length; such a system is, therefore,

essentially self-tuned and no coil, condenser or earth connexion is necessary. The wavelength to which such a wire will tune is termed its fundamental wavelength and is approximately twice its own length. For this reason such an aerial is often called a *half-wave* aerial. It is generally more efficient than the Marconi type but, because its physical length is related to wavelength, its use is chiefly confined to short waves.

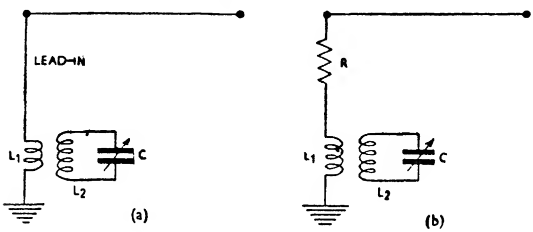


Fig. 2. In (a), the aerial, together with L_1, is not tuned to the required station which is, however, selected by the tuned circuit L_2C. The inclusion of the resistance R in series with the lead-in (b) helps to make the aerial *aperiodic* and is sometimes used to reduce the signal from a nearby powerful transmitter.

A loop or frame aerial is simply a tuning coil of large physical dimensions and is tuned by means of a condenser.

Aerials for domestic broadcast reception are generally not tuned to the required programme, or are so arranged as not to respond to any particular frequency at all; in the latter case they are said to be *aperiodic*. The actual programme selection is carried out by means of an independent tuned circuit (Fig. 2). The aerial itself, together with its lead-in, may consist of about 50 feet of wire elevated as high as convenient and kept away from obstructions such as gutters, trees and telephone wires. It should be well insulated at the fixing points and where it enters the building.

Aerials do not usually radiate in, or receive uniformly from, all directions and they thus possess directive properties of which much use is made for direction-finding. Directive aerial systems may be roughly divided into three main classes: (1) a number of half-wave aerials or dipoles may be so arranged as to favour one particular direction and are called *beam arrays*, (2) long electrically resonant wires which are known as *progressive wave* aerials and (3) loop or frame aerials.

AERODYNAMIC CENTRE. That point in an aerofoil section (q.v.) about which the pitching moment coefficient of the aerofoil is constant. The pitching moment is independent of the angle of incidence (within the normal range) and changes only if the aeroplane speed is changed. Aerofoil theory indicates that the aerodynamic centre should be at 25 per cent of the chord from the leading edge, but in practice it is found to lie between 23 and 25 per cent. The exact position depends on the shape and thickness-chord ratio of the aerofoil section.

AERODYNAMIC MEAN CHORD (A.M.C.), see MEAN CHORD.

AERODYNAMICS. The study of air in motion, or of the effects of the passage of bodies through air and its relation to their performance. All aircraft manufacturing companies have a section or department dealing with aerodynamics. The duties of such a department comprise the estimation of aircraft performance, the investigation of problems of stability and control, the observation and analysis of performance tests on complete aircraft, and aerodynamic research, which may consist of either full-scale or wind-tunnel experiments.

AEROFOIL SECTION. A shape used for the fore-and-aft cross-section of aeroplane wings and tail surfaces, also the blade sections of propellers.

The main features of an aerofoil section are shown in Fig. 1 overleaf. The mean camber line is a line drawn midway between the upper and lower

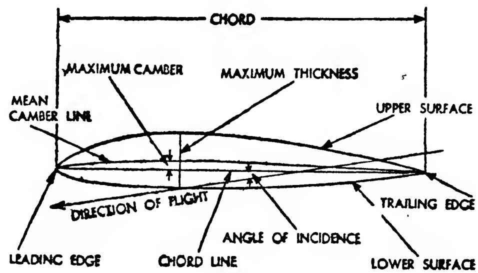


Fig. 1. Main features of a typical aerofoil section, consideration of which is essential in aeroplane design and construction.

surfaces. It has been usual for the maximum thickness and maximum camber to occur at about 30 per cent of the chord from the leading edge, but there is a modern tendency to use sections with maximum thickness at 40 or 50 per cent of the chord. The reason for this development is that such sections are more suitable for use at high speeds (approaching that of sound) or for promoting the maintenance of laminar flow (q.v.) over a large proportion of the chord. It is not necessary for the maximum camber and the maximum thickness to occur at the same point.

The characteristics of an aerofoil section depend mainly on two factors; the ratio of the maximum thickness to the chord, and the ratio of the maximum camber to the chord, each expressed as a chord percentage. The first, usually known as the thickness-chord ratio, is the main factor governing the drag of the section. As might be expected, an increase in drag results from an increase in thickness-chord ratio. The second, which is usually referred to as the camber, governs the no-lift angle of the section and the corresponding pitching moment. Owing to the fact that the resultant lift force acts at a point well back from the leading edge, this lift force has a turning moment about the leading edge. This is known as the pitching moment of the aerofoil section.

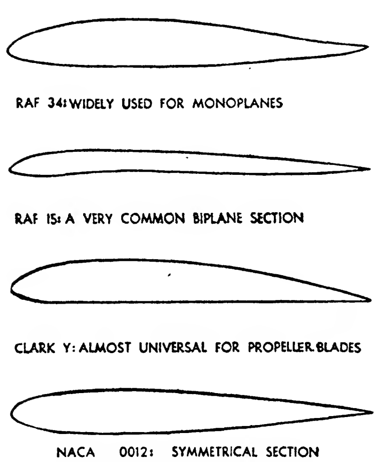


Fig. 2. Diagram showing some typical aerofoil sections and their application.

There is a modern tendency to quote the pitching moments of aerofoils about the quarter chord point instead of about the leading edge. This is done because the quarter chord point approximates to the aerodynamic centre of the plain wing, and the pitching moment coefficient about this point is therefore practically independent of incidence.

The no-lift angle is the angle of attack at which the lift of the section vanishes. For a symmetrical aerofoil section which has no camber, top and bottom surfaces being equidistant from the chord line, the no-lift angle is obviously zero. Cambered sections have a negative no-lift angle and produce a positive lift at zero angle of attack. Similarly, the pitching moment at zero lift is zero for a symmetrical section, but a cambered section has a nose-down pitching moment at zero lift.

The negative value of the no-lift angle and pitching moment at zero lift both increase as the percentage camber is increased. Typical examples

of aerofoil sections, of which a great number have been designed for various purposes, are shown in Fig. 2, and their usual applications indicated.

The upturned trailing edge of the R.A.F. 34 section, known as a reflex camber, was designed to reduce the pitching moment of the section at zero lift to zero, while retaining the camber on the forward part of the section.

AEROGRAPH. A pneumatic device for distributing or laying paint in an atomized form as a spray. It consists of a pump to supply air under compression which may be actuated by hand, foot, or motor; a cylinder to contain air

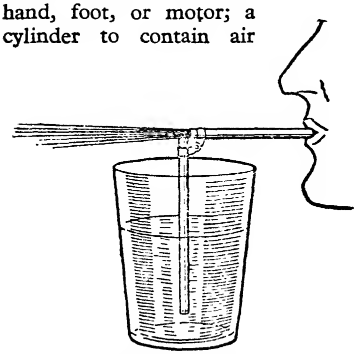


Fig. 1. Earliest means of spraying still widely used for fixing artists' drawings.

under compression, a convenient container for the paint and a gun for distribution. The feed may be by suction, the current of air being directed over the top of a pipe suspended in the container; by gravity, from the container situated over the distributor; or by pressure-feed from a container holding the paint under compression. The nozzle of the gun may be adjusted to deliver the paint either as a fine jet or fanwise. These machines vary in size and cost according to the type of work to be executed, the smallest being supplied for use in the drawing office and the largest to operate a battery of several guns for limewashing and painting large surfaces. The equipment necessitates a considerable outlay of capital, but cuts down very considerably the number of man-hours required to apply a given quantity of paint as against its application with a brush. Although opinions differ as to the lasting qualities of paint applied as a spray, there are many jobs which can best be executed by this method; but the general opinion is that priming should always be done by brushing. In the guns illustrated (Figs. 2 and 3) the pumps are operated by petrol or electric motors to obtain compression in the paint and air containers; the trigger is merely for controlling the jet.

AEROPLANE. A flying machine which is sustained by the lift forces, due to the motion of the machine through the air, acting on fixed aerofoil surfaces.

In this respect aeroplanes are quite distinct from balloons or airships, which are generally known as displacement craft, i.e., they weigh less than the volume of air they displace. For this reason they are often called lighter-than-air craft. The aeroplane, by reason of its passage through the air, creates a partial vacuum above the upper surface of the wing, thereby obtaining lift. This lift is greatly influenced by the cross-sectional shape of the wing or plane, known as the aerofoil.

For a more detailed explanation of the principles and theories involved see AEROFOIL SECTION, AILERON and ANGLE OF DOWNWASH.

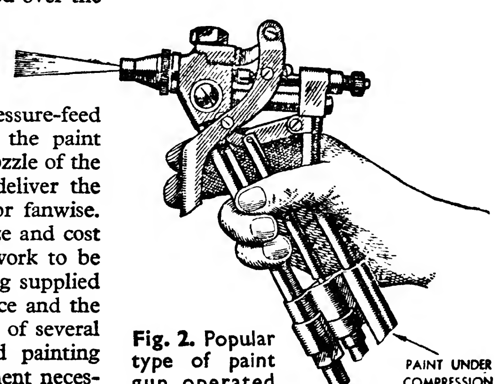


Fig. 2. Popular type of paint gun operated by compressed air from pump.

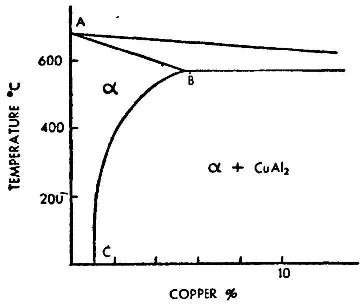
A.F. (Radio). Audio frequency (q.v.).

A.F.C. Automatic frequency control, see TUNING.

AFTER-COOLER, see INTER-COOLER.

AGE-HARDENING. A process that can be applied to a variety of alloys, but is best known in its application to certain aluminium alloys. The process consists of two parts. First, the alloy is solution-treated by being heated to a certain temperature and quenched in water. In this state the alloy is soft and can be readily worked. With some alloys hardening begins to occur immediately after quenching and may continue for days—hence the name. In most cases, however, it is necessary to temper the alloy for a definite period of time at some temperature below that to which it was first heated.

Overheating leads to resoftening of the alloy. All alloys susceptible to this process possess equilibrium diagrams of similar form. The one shown—that for copper-aluminium alloys—is typical. Heating an alloy containing say 4 per cent copper to a temperature above the line BC, results in the solution of any copper-aluminium compound ($CuAl_2$), which exists in the form of small particles, to form a uniform solid solution. On quenching, this uniform structure is retained, but



Alloys treated by the age-hardening process have an equilibrium diagram similar to the one for copper-aluminium.

on subsequent tempering at a temperature below the line BC, very fine particles of the $CuAl_2$ compound begin to separate. The greatest hardening effect is obtained before these particles become large enough to be visible under the microscope. Prolonged tempering results in the growth of the particles with subsequent loss of strength and hardness.

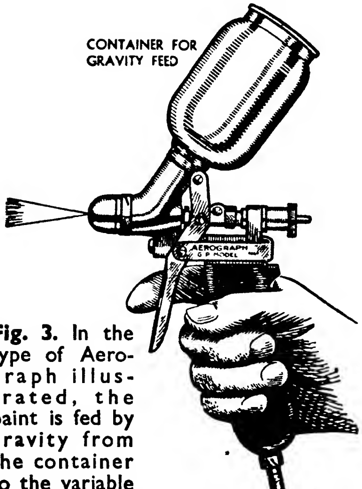


Fig. 3. In the type of Aerograph illustrated, the paint is fed by gravity from the container to the variable nozzle of gun.

AGEING. In electrical engineering, changes in the magnetic properties of iron. The term is also used in reference to acoustic appliances when, due to wear, the carbon granules have become smooth through frictional movement. In metallurgy, the term expresses an increase in tensile strength and hardness which takes place in certain metals at atmospheric temperature after heat treatment or after cold-working. See STRAIN AGEING.

AGGREGATE, see CONCRETE.

AILERON. The control surface which enables the pilot to regulate the movements of an aircraft about the rolling axis. It is an inset hinged portion of the outer part of the trailing edge of the wing which is operated by the pilot's control column. Thus, movement of the "stick" or control wheel to the right raises the right aileron and lowers the left aileron thus causing the right wing to drop and vice versa.

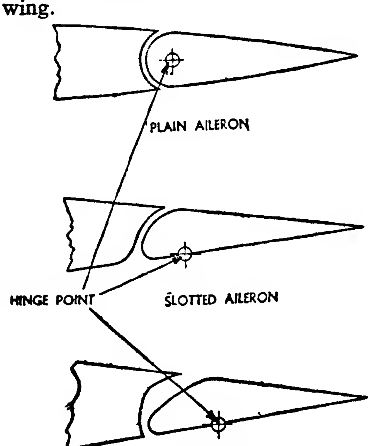
Ailerons are often of the differential type, which means that the travel of the upgoing aileron is greater than

that of the downgoing one. There are two advantages resulting from the use of differential ailerons:

(a) If both upgoing and downgoing ailerons have equal travel (known as square-rigged ailerons) the drag caused by the downgoing aileron is greater than that due to the upgoing one. This has the effect of producing a tendency to turn the nose of the aircraft in an opposite direction to that appropriate to the bank being applied, i.e., when banking to the right, forces are set-up, tending to turn the nose of the aircraft to the left, which is undesirable. Differential gearing can be arranged to eliminate this adverse yawing moment.

(b) The differential has the effect of lightening the force which the pilot has to apply to roll the machine to a given angle. This control-balancing effect is, however, most pronounced at low speeds, whereas the greatest need for reducing the control forces exists at high speeds.

The adverse yawing effect can also be controlled by the Frise aileron, shown in the illustration, in which the extension in front of the hinge protrudes downwards when the aileron is raised, causing extra drag on the inner wing.



Ailerons, of which the above are common types, are hinged to the rear tip of the wings and vary in length and shape according to requirements of each individual type of aircraft.

AIR BRAKE (Aero. Engineering). A device to increase the aerodynamic drag of an aircraft. Air brakes may be designed either to steepen the gliding angle during the approach to land or to limit the speed in a steep dive for dive-bombers. Flaps as fitted to the wings of nearly all modern aircraft act as air brakes and steepen the approach in addition to increasing the maximum lift. See FLAP.

AIR BRAKE (Mech. Engineering). A friction brake operated by compressed air—e.g. Westinghouse—and used mainly in locomotive traction. The actuating mechanism consists of a cylinder and piston, compressed air being admitted, either to force the brake shoes on to the drum or to release them against the pressure of a spring.

An alternative type is the *vacuum* brake, in which, so long as a vacuum is maintained throughout the system, the brakes are in the "off" position, as soon as the vacuum is broken by the admission of air, the brakes come into operation. Both compressed air and vacuum types are now applied to heavy road-transport vehicles.

AIR BRICK. A perforated brick fixed in a wall so that a free current of air can pass through for the purpose of ventilating (a) the cavity of a cavity wall, or (b) the space under the ground floor of a building. In (a) air bricks are placed near the base and top portion of walls, thus permitting a free circulation of air in the whole of the cavity, and in (b) they are usually placed just below ground-floor level to allow air to pass through the wall to the underside of timber floor-joists to ventilate the space between the joists and the top of the surface concrete.

AIR BRUSH, see AEROGRAPH.

AIRCRAFT. Any vessel or mechanical structure capable of maintaining itself in the air, e.g. aeroplane, seaplane, balloon, airship.

AIR DUCT. An enclosed channel used in all forms of building and engineering to convey air from one point to another. Air ducts, according to their size and purpose, may occa-

sionally be constructed of brickwork in the form of flues and tunnels, but are more often made of sheet metal, usually of light gauge, varying from 16 to 24 S.W.G. in thickness. The cross section may take any form to suit particular circumstances, but square, rectangular or cylindrical ducts are most commonly employed. For ventilation purposes, rectangular ducts may be built into walls or taken across ceilings and made to harmonize with the scheme of decoration. Cylindrical ducts are generally employed in blowing systems, such as those required for blacksmith's hearths, and, for steam and fume exhaust systems, where the air velocity is relatively high. Cylindrical ducts are not only more efficient in relation to air flow, but also more economical in the use of material.

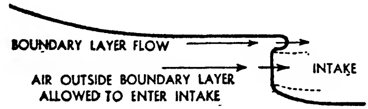
The two methods generally adopted for joining lengths of duct are: (1) the fitting of angle rings to the ends of the separate lengths for the purpose of bolting them together; (2) the use of slip joints, in which one length is made to slide into the next for a few inches after the manner of the telescope. The latter method, while not so strong or air-tight as the former, allows more freedom in fitting on site. See DUCT.

AIRFRAME. The structure of the complete aircraft, excluding the engines and engine installations.

AIR GAP. The gap, or gaps, in the magnetic circuit of an electrical component, instrument or machine. For example, in a motor or generator air gaps are necessary to permit relative movement of the fixed and moving parts.

The length of the gap is usually measured radially, that is, parallel with the direction of the lines of force. See MAGNETIC CIRCUIT.

AIR INTAKE. Any opening through which air is admitted to an engine or system for cooling, ventilating, supplying oxygen etc. Carburettor air intakes on internal-combustion engines may incorporate filters to prevent sand and grit entering when operating in sandy or dusty conditions. Conversely, a control may be provided to enable the engine to be supplied with warm



Air intake with boundary-layer lip so placed as to obviate turbulence in the air entering the apperture.

air from inside the engine cover in cold climates.

In aircraft, it is desirable that the air intake should have the smallest possible drag and allow the air to flow smoothly into it without any turbulence. For this reason the inner edge of the intake is placed a small distance away from the under-surface of the aircraft as illustrated. This prevents the air in the boundary layer from entering the intake, where it would be likely to provoke the onset of turbulence and loss of efficiency.

AIR POCKET. Air conditions which cause an aircraft to drop suddenly. In extremely rough flying conditions a drop of hundreds of feet may take place. This may be due to downward air currents, or, with aeroplanes, to a change in the direction or velocity of the wind, that is, when the wind velocity decreases in the direction of flight, so that the inertia of the aeroplane causes a momentary loss of airspeed, and therefore lift.

AIR SCOOP. The term commonly used in the U.S.A. to denote an air intake.

AIRSCREW, see PROPELLER.

AIRSHIP. A lighter-than-air craft, consisting of an envelope filled with gas, which remains aloft because it displaces a weight of air greater than its own weight, i.e., which floats in the air as a submarine floats below the surface of the water. As it is not dependent on its forward speed for its lift, it can, unlike the aeroplane, remain stationary in the air with engines off, or even fly backwards. Airships may be divided into two main types, non-rigid and rigid. The non-rigid airship has no structure enclosing the gas-bag or bags, and the weight of the underslung section containing crew, engines etc., is

supported by means of cables connected to points well distributed over the length of the bag. This form of construction is limited to the smaller types. The rigid type has a light alloy girder framework with several gas-bags known as balloonets distributed inside it. The gas used is as a rule either hydrogen or helium. Hydrogen is lighter but inflammable, hence a hydrogen airship can carry more load than a helium airship of the same size, but runs the risk of fires and explosions when escaping hydrogen becomes mixed with air. These risks are eliminated when helium, a non-inflammable gas, is used.

AIR SPEED. The speed of an aeroplane relative to the surrounding atmosphere. Indicated air speed is the reading of the air-speed indicator, which is incorrect at all altitudes other than sea level, or the level at which it is calibrated. The indicated air speed (after correction for compressibility and position error) is multiplied by the square root of the air density at sea level divided by the square root of the air density at altitude of flight to convert it to true air speed.

AIR-SPEED INDICATOR. An instrument, shown in the accompanying diagram, which measures the speed of an aircraft through the air. A pitot head, consisting of two tubes, is mounted in some convenient point on the aircraft, clear of the slipstream and other aerodynamic effects, often projecting from the leading edge of the wing. The end of one tube is open to the air flow, the other is closed but has several small holes in the side. A difference in air pressure inside the tubes is thus obtained when the aircraft moves forward, a difference which is roughly proportional to the density of the air multiplied by the square of the aircraft's speed. This difference is transmitted by piping to the air-speed indicator, the closed tube being connected to the casing of the instrument, while the open tube is connected to the inside of an expanding capsule made of thin corrugated metal. As the capsule expands owing to the additional pressure within, its movement is magnified and transmitted to the pointer of the instrument.

AIRWORTHY. Fit to take the air; having a certificate of airworthiness. An aircraft is said to be airworthy when it has been designed in accordance with the relevant requirements of its duty, when its structure is sound, and when all controls, instruments etc., are in proper working order. The first civil aircraft of a new type is tested by the Air Registration Board before a certificate of airworthiness is granted. Subsequent aircraft of that type are automatically granted a certificate of airworthiness if the builders certify that they conform to the tested prototype. The certificate of airworthiness has to be renewed annually, which entails a thorough inspection of the aircraft. Aircraft carrying passengers must be inspected daily before flight by a qualified ground engineer.

ALBITE, see FELSPARS.

ALCLAD. A registered trade name used by the Aluminium Company of America for certain strong alloys coated with aluminium of 99·7 per cent minimum purity. The surface layer of the aluminium is alloyed and is integral with the core; it is normally not more than about 5 per cent of the total thickness on each side. Methods of manufacture include casting an ingot of aluminium alloy, such as Duralumin, in a steel mould lined with pure aluminium, the mould being water-cooled to prevent excessive diffusion into the pure aluminium. The ingot thus produced is then rolled to size. The coating not only protects the core against

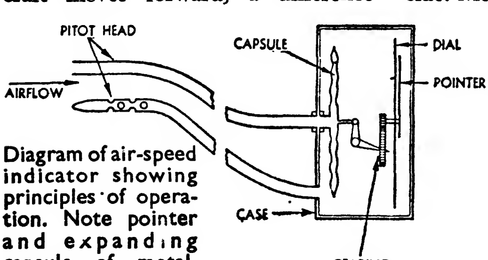


Diagram of air-speed indicator showing principles of operation. Note pointer and expanding capsule of metal.

direct corrosion, but, by electrolytic action, prevents attack on the sheared edges or on other exposed sections of the base metal. Alclad is extensively used in the aircraft industry for all parts, e.g., seaplane floats, where corrosion conditions are unusually severe. The tensile and yield strengths are approximately 10 per cent lower than for the extruded alloys, and slightly heavier gauges of metal are used to compensate for this; alternatively, a core of higher strength (D.T.D. 390) may be used.

The clad surface may also be anodically treated before being painted in order to attain the maximum adherence of the paint. Alclad is normally supplied in sheet and strip form. See EXTRUSION OF METALS.

ALCOHOL (Ethyl alcohol, ethanol, spirits of wine, CH_3CH_2OH). A colourless liquid boiling at 78·32 deg. C. It is miscible with water, dissolves some inorganic salts and many organic compounds. It is manufactured by fermenting starch or sugary materials with yeast. When starch is used for this purpose it is necessary to break-down the starch into sugars by adding malt which contains an enzyme (diastase) that effects this breaking-down.

Absolute alcohol, which contains 100 per cent of alcohol, is obtained by distilling ordinary alcohol which contains about 4½ per cent of water with benzene and a low-boiling petroleum. Alcohol is also made synthetically from acetylene or ethylene, the ethylene being obtained from the cracking of petroleum. Commercial alcohol is used as a solvent and diluent for shellac in the production of knotting and shellac lacquers; combined with organic acids it produces solvents of sufficient power to break-down resins and the oxidized films of paint varnish and enamel.

Methylated spirit, a combination of spirits of wine, wood alcohol (naphtha), mineral oil, crude pyridine and colouring matter, is manufactured for burning, and is not satisfactory as a solvent for shellac or for use in connexion with French polishing. See CARBOHYDRATES.

ALIGNMENT. The setting in position along a true line (a straight line is normally implied) of a number of components in a machine or structure, to ensure satisfactory operation. The fast and loose poppets on a lathe, for example, should lie on one common centre line; they are then said to be in alignment.

In mechanical engineering the term is also applied to shafting and shaft bearings in a workshop, and to the bearings of an engine crankshaft, to denote linear accuracy or uniformity. In civil engineering the term has a special significance as applied to the setting in line (generally straight) of successive portions of railway track, when under construction or repair. It may also denote the layout, or plan view, of a roadway or embankment.

ALIGNMENT (Radio). Adjustment of the tuned circuits of a receiver so that they work at the correct, predetermined frequency.

ALKALI. A substance which, when dissolved in water, forms a non-acid solution. The term is now used chiefly in connexion with the industry which includes the manufacture of sodium carbonate, sodium hydroxide (caustic soda), potassium carbonate, potassium hydroxide (caustic potash), ammonia liquor, ammonium carbonate, calcium oxide (lime), and barium oxide (baryta). All alkalis will turn red litmus paper blue, and when added to an acid they neutralize it if present in the right proportion. Weak alkaline solutions are employed to remove all deposits of grease during the preparation of surfaces to be painted.

Stronger solutions will completely break-down the fabric of paint and varnish, whatever its age, so that it may be easily removed with a broad knife or simply washed off with water. All surfaces so treated require additional treatment with weak acid, normally vinegar, to neutralize any caustic material which may have been absorbed by the washed paint, or by the plaster or timber surfaces from

which the paint has been removed. Care should be taken in the preparation of strong solutions: always add the dry caustic material to the water a little at a time, never add water to the bulk of the dry material; the reaction upon contact is so violent that scalds and burns may result.

ALKALINE CELL, see NICKEL-IRON CELL.

ALKYD RESINS, see GLYPTAL SYNTHETIC RESINS.

ALL-DRY RECEIVER. A radio receiver in which all the power supplies are derived from dry batteries.

ALLOTROPY. The existence of different varieties of the same element: thus, carbon exists in three allotropic varieties, diamond, graphite and charcoal. The first two are crystalline and the third is amorphous. There are several varieties of phosphorus, one white and soluble in carbon disulphide, another red and insoluble in carbon disulphide. Oxygen exists in two varieties, ordinary oxygen and ozone.

There are two allotropes of tin, the one a shining metal, the other a dull-grey powder, the latter being produced at temperatures below 18 deg. C. If tin or pewter, which contains tin, is kept for a long time in a very cold room it gradually turns into this grey variety and its appearance is spoilt. Iron changes its crystalline form on being heated above 906 deg. C. from a body-centred to a face-centred cubic lattice. In addition to a change of crystalline form, other properties of the metal may be altered; α iron can dissolve only 0·03 per cent carbon, by γ iron may contain up to 1·9 per cent of this element. Allotropic modifications occur only at definite temperatures, but a change may be prevented by drastic quenching.

ALLOY. A substance possessing metallic properties, consisting of two or more elements of which at least one must be a metal. Thus bronze is an alloy of copper and tin—both metals; but phosphor bronze, in addition to copper and tin, contains a small proportion of phosphorus—a non-metal.

Alloys which are composed of two elements are termed binary; of three, ternary, and so on. They are usually made by melting together the appropriate amounts of the required constituents to comprise a uniform liquid. On solidification, an alloy may remain uniform, when it is said to form a solid solution in which each constituent is dissolved in the others. Copper-nickel alloys are of this type. On the other hand, separation on a microscopic scale, into two or more distinct substances may occur, the substances, or phases, being pure metals, solid solutions of a limited range of composition, or chemical compounds of fixed composition.

Thus lead-tin alloys in solid state consist of two phases, one being pure tin and the other a solid solution of tin in lead containing not more than 16 per cent of tin, the relative proportion of the two phases depending on the composition of the alloy. On solidification, iron-carbon alloys form a solid solution of carbon in iron and a chemical compound, iron carbide—Fe_3C. On cooling to room temperature the solid solution dissociates into pure iron and iron carbide. In general, alloys possess physical, mechanical or chemical properties, or combinations of these properties, superior to those of their constituents.

ALLOY—FERROUS. An alloy in which iron is a principal constituent. Although the term non-ferrous alloy is of common usage, it is very rare to hear the term ferrous alloy, for the reason that the range of alloys whose base is iron merges almost imperceptibly, with successive diminutions of alloying element, into plain carbon steel which, by common consent, is not normally considered a ferrous alloy.

The line of demarcation is drawn as follows: an alloy steel is one in which elements, other than carbon and manganese, have been purposely added with the intention of producing particular properties in the finished steel. Carbon and manganese are in a

different category, because although in the strict sense of the word they are alloying elements, a plain carbon steel is not regarded as an alloy steel; manganese is almost invariably added to steel for deoxidation purposes, as well as to counteract the harmful effects of the sulphur impurity. Manganese up to about 2 per cent is therefore not normally considered as justifying the suffix alloy to the steels of which it forms a part; there are, however, manganese alloy steels, notably the austenitic 12 to 14 per cent type used extensively where resistance to wear and shock is of importance. A well-known sheet application of this is the pressed steel helmet of the British armed forces. Among the more commonly used alloying elements in steel are manganese, silicon, nickel, chromium, copper, aluminium, cobalt, tungsten, vanadium, titanium, molybdenum, sulphur and lead.

The most important ferrous alloy is that of iron and carbon. With up to about 1·8 per cent carbon it is spoken of as steel; with over this quantity, up to about 6 per cent, as cast-iron. Instead of considering steel and cast-iron as ferrous alloys it is more usual to take them, as above defined, as simple metals. Consequently, the terms alloy steel and alloy cast-iron are more commonly used. In the manufacture of alloy steel or cast-iron the alloying metal or metals have to be added. For this purpose a ferro-alloy (q.v.) containing a high proportion of the alloying metal is often used, the balance being iron. The term ferro-alloy has a separate significance, and is used for a ferrous alloy which is prepared solely for the purpose of adding an alloying metal.

ALL-WAVE RECEIVER. A radio set which can be tuned to short-wave as well as to medium and long-wave stations.

ALPAX ALLOY. An alloy of aluminium and silicon, the proportion of the latter element, which imparts to the alloy its characteristic qualities, being from 10 to 13 per cent. Its most important feature is its work-hardening property; this makes it very suitable for manufacture into sheets. Although the tensile strength of the ingot as cast is rather low, the work-hardening propensity raises the strength of the rolled sheets, on which a considerable amount of work has been done, to anything up to 16 tons per sq. in., with an elongation of about 15 per cent.

Another alloy, similar to Alpax, is known as L. 33. It has been found that the addition of a small quantity of sodium brings about a notable refinement in the metallic structure by limiting the crystal size and so causing a definite improvement in mechanical properties; moreover, the metal is more malleable in the condition as cast and also shrinks less than other alloys while solidifying, an important point in the production of sound castings.

ALTERNATING CURRENT. A direct current is constant in amount and flows continuously in the same direction, but this is not the only possibility. The current may vary in amount while keeping the same direction, in which case it is said to be a pulsating current, or it may vary both in amount and direction and so constitute an alternating current. In this article, the term alternating current is used to mean a current which varies sinusoidally. This means that if the instantaneous current is plotted vertically on a graph at positions which correspond to various time intervals, the result is a sine wave (q.v.). A sine wave is illustrated by the wavy line in Fig. 1.

Visualize current as flowing to and fro in the wire in much the same way as does air in the human windpipe when a person is breathing rhythmically. Current in this case corresponds to the rate of flow of the air. One cycle is equivalent to one breath drawn in and exhaled, and the number of cycles per second is the frequency. Of course, the to and fro motion of an electric current is generally much faster than the most rapid breathing, for the usual frequency of power supplies in this country is 50 cycles per second, which would correspond to 50 breaths per

second. The period is the time taken to breathe in and out and so it is the reciprocal of frequency; for A.C. at 50 cycles per second the period is 0·02 sec.

For approximate purposes, the speed of the air into and out of the mouth may be taken to represent the rate of flow. Suppose now that an anemometer is placed in front of the mouth of the subject of this imaginary experiment. The reading of speed will vary all the time, from nothing when the chest is fully expanded, rising to a maximum reading in the middle of the breath and falling again to nothing when the chest is fully deflated. If we call these readings positive, then those obtained on breathing-in will be negative because the air is going the other way. Any snap reading of the anemometer is an instantaneous value and the greatest speed recorded is the peak or crest value. The period of breathing out constitutes a positive half-cycle while the inhaling period is a negative half-cycle. All these definitions are illustrated in Fig. 1.

We must now leave the experiment and think in electrical terms. The size of an alternating current is not usually stated in terms of its peak value, but in terms of a mean value. There are two mean values. One is what is normally understood by the term average, but reckoned over half a cycle only. This value is called the mean value, or arithmetic mean value. The other, the R.M.S., or root mean square value, is obtained as follows. The height of the curve is measured at a number of points, the results are squared and each plotted vertically at the place where the original measurement was made. By joining this series of points a new curve is obtained and the square root of the arithmetic mean value of this new curve is the R.M.S. value of the original curve.

For sine waves, this performance is not necessary because it is known that the R.M.S. value of a sine wave is $\frac{1}{\sqrt{2}}$ times the peak value. R.M.S. value is the one normally used to describe an alternating current. Thus 5A is read to mean a current having an R.M.S. value of five amperes.

All the foregoing applies equally to alternating voltages except, of course, that they are measured in volts. In any A.C. circuit, unless it contains nothing but resistance, the current and voltage do not reach their maximum, or peak, values at the same time. A similar effect is observed in the breathing experiment where the rate of flow is nothing when the chest pressure is greatest, that is, when it is fully expanded. When two alternating quantities differ in this way, they are said to be out of phase, or there is a phase difference between them. The one which is ahead is said to lead, while the

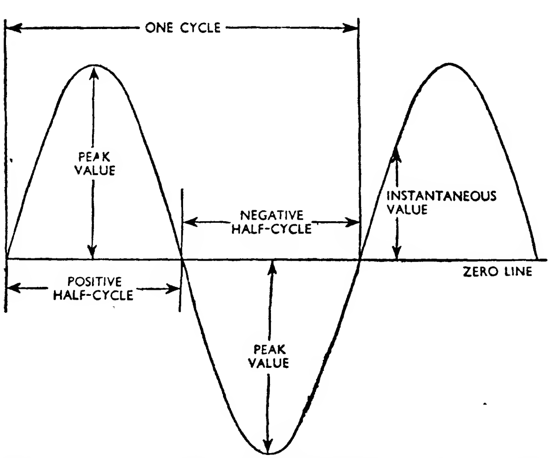


Fig. 1. This sinusoidal curve shows the way in which alternating currents and voltages vary with time. The instantaneous value is any point chosen at random and may be positive, as in the case shown in the above diagram, or negative during a negative half-cycle.

other is said to lag.

In making A.C.-circuit calculations and, indeed, for understanding the behaviour of circuits, it would be unbearably tedious if it were necessary to draw-out correctly a whole series of sine waves in their correct relative positions. Fortunately, this can be avoided by the use of electrical vectors. A vector may be envisaged as the spoke of a wheel, without the wheel. It rotates at a constant speed about one end, normally in the anti-clockwise direction. Fig. 2(a) shows sine waves of voltage and current which differ in phase. To represent these by the vectors OV and OI in Fig. 2(b) it is necessary to make the lengths OV and OI equal to the peak value of the voltage and the current and to see that the speed of rotation is such that the time of one revolution is the same as the period. The angle ϕ between the vectors must be the same fraction of a revolution (360 deg.) as the distance marked ϕ in Fig. 2(a) is a fraction of the whole cycle. It is also necessary that the voltage and current have the same frequency, which means that the vectors remain in the same relative position as they rotate together, and that the lengths representing one cycle of voltage and current are the same.

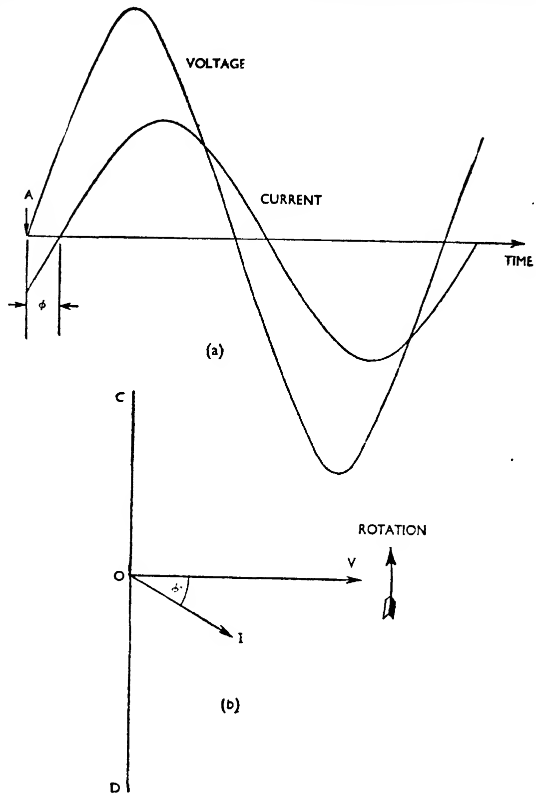


Fig. 2. Diagram (a) shows a voltage and a lagging current. The vector diagram (b) represents the same thing, and is drawn for the instant marked A in diagram (a). For any position of the vectors their projections on to CD in diagram (b) are equal to the heights of the waves at corresponding instants.

This applies nearly always in A.C. circuits and no other case will be considered here. The two vectors may be imagined as two spokes of the same imaginary wheel.

If all these conditions are met it will be found that the height of the points V and I above or below the horizontal are equal to the corresponding values of the voltage and current. Thus the position in which the vectors are snapshotted in Fig. 2(b) corresponds to the instant of time at which the voltage is zero and about to increase positively.

In a single-phase A.C. circuit there is but one applied voltage and only one current, if the circuit is series-connected. Fig. 2(b) might be the

vector diagram for such a circuit, containing resistance and inductance, except that the lengths of the vectors would be made equal to the R.M.S. values and not the peak values. This amounts merely to a change of scale.

With this proviso, the impedance of the circuit would be $\frac{\mathrm{OV(Volts)}}{\mathrm{OI(Amps)}}$, the power would be OV(Volts) $\times$ OI(Amps) $\times$ Cos. ϕ (see POWER FACTOR), the active component (q.v.) of current would be OI(Amps) $\times$ Cos. ϕ and the reactive component (q.v.) would be OI(Amps) $\times$ Sine ϕ.

For various reasons it is often desirable that there should be no phase difference between the current and voltage, that is to say that the vectors are different lengths marked along the same spoke. The vectors are then said to be in phase and the condition is known as unity power factor since $\phi = 0$. To achieve this it may be necessary to use power-factor correcting plant such as ordinary or synchronous condensers (q.v.).

In a polyphase circuit there are a number of voltages, usually two, three, six, or twelve, but generally three, which might be employed separately to feed independent circuits, but are, in fact, almost always interconnected. Taking the three-phase case, as the most usual, it will be found that a three-phase alternator has three separate armature windings so disposed that they generate three equal voltages differing in phase by 120 deg. They are represented as vectors in Fig. 3(a) and are labelled R, Y, and B.

When the three windings of the alternator have their starting or finishing ends connected together to a common star-point (q.v.) a star connexion is made. Fig. 3(b) shows this arrangement connected to a star-connected load by means of a three-phase four-wire system (q.v.). It also illustrates some other terms to which reference may usefully be made.

The voltage between any pair of lines, such as the one marked V_L, is the line voltage and it may be shown to be $\sqrt{3}$ times the voltage between

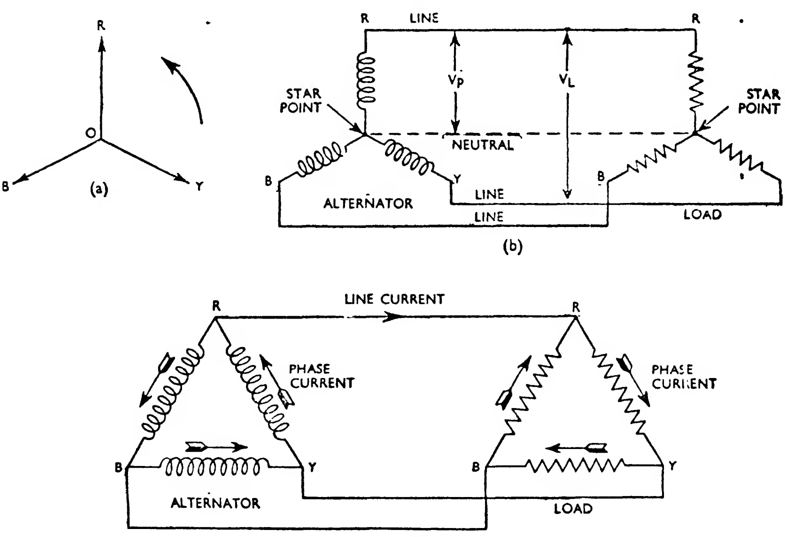


Fig. 3. Vectors shown at (a) represent voltages generated in the three windings of the alternators in diagrams (b) and (c). At (b), both alternator and load are star-connected, whereas in (c) both are delta-connected. In (b), the line and phase currents are the same but, in (c), the line current is $\sqrt{3}$ times the phase current.

any line and neutral, such as the one marked V_p. It is in this manner that a 400/230-V. system is arranged.

Three equal resistances are shown as the (balanced) load but they might equally well be a star-connected machine. In either case the currents in the three lines are equal and, like the voltages, are spaced at 120 deg. when represented as vectors, though they are not necessarily in phase with the voltages.

Three-Phase Connexions

The three currents all meet at the star point of the load and their resultant flows, by way of the neutral, back to the alternator. However, since the currents are equal their total sum at any instant is nothing and there is no current in the neutral wire. Consequently the neutral is unnecessary, provided that the load is balanced, as in this case, and it may be omitted, leaving a three-phase three-wire system. The above statement may be investigated by drawing-out three sine waves, spaced one third of a cycle apart, and adding them point by point, remembering that negative and positive currents must be regarded as flowing in opposite directions. Alternatively the currents may be added vectorially. To do so, start at any point such as O. Proceed along vector R to its end, then move in the direction of Y for an equal distance and finally in the direction of B, for a similar distance. The sum of the vectors is the line joining the finishing point to the starting point and proves to be just non-existent. The vectors may be added in any order with the same result.

The other common three-phase connexion is known as a delta, or mesh, connexion (q.v.). It is illustrated in Fig. 3(c) which shows a delta-connected alternator and a delta-connected load. It might be thought that this arrangement would short-circuit the alternator, but this is not the case. An argument similar to the one set out above will show that the total voltage round the triangle, which is the vector sum of the three voltages, is again nothing, so that there can be no circulating current. For this to be true the alternator windings must be connected start-to-finish and so on.

ALTERNATOR. In an electromagnetic generator, the main principles of which are shown in the accompanying diagram, there must be a winding, called an armature winding, in which the e.m.f. is generated, a magnetic field, and some means of causing relative motion of the two. The magnetic field might be, and in some cases is, produced by a permanent magnet. Cycle dynamos usually work in this manner, and so do magnetos.

In general, alternators have electromagnetic fields energized by D.C., which necessitates either a D.C. supply or an additional machine in the form of a D.C. generator, called an exciter because it provides the field current for excitation.

In general practice it is usual to make the field magnets the rotating part of the machine, though the opposite construction is sometimes encountered in small machines, because only two slip-rings are needed and the insulation need withstand only a low voltage.

The rotor may be cylindrical with the exciting winding carried in slots (see CYLINDRICAL ROTOR) or of the salient-pole construction, in which case the field windings are in the form of bobbins round the poles. A diagram of the salient-pole rotor is given under POLE.

The armature winding is carried in slots (illustrated under that heading) on the inner cylindrical face of the stator, that is, in the core, and is usually connected to give a three-phase output (see ALTERNATING CURRENT).

The iron core is usually built up from laminations (under which heading an illustration appears) mounted in the stator frame in such a manner as to leave adequate space for the circulation of air for cooling purposes.

End-connexions are secured to the stator to avoid risk of movement under the action of electromagnetic forces. These forces depend on the square of

the current and are very large under short-circuit conditions.

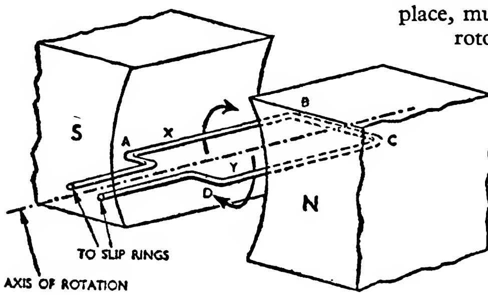
The manner in which an e.m.f. is generated may be seen by referring to the illustration which, for simplicity, depicts a single coil able to rotate in a magnetic field. Flux passes from the north pole, marked N, to the south pole, marked S, and is most dense in the position in which the coil is drawn. At this point the conductors, X and Y are cutting flux most rapidly so that the e.m.f., which is proportional to flux and speed, is maximum. The direction of the e.m.f. may be found by using the right-hand rule. This shows that in conductor X it is directed from B to A while in conductor Y it is from D to C, so that the two e.m.fs. are additive.

As the loop rotates, the flux becomes less dense so that the e.m.f. gradually falls until, when the loop is vertical, there is no e.m.f. at all. Continued rotation produces a growing e.m.f., which is now in the opposite direction because the wires X and Y have changed places. This e.m.f. reaches a maximum when wire X occupies the place of wire Y in the diagram, falls to zero when the loop is vertical and then grows in the original direction.

Thus the e.m.f. alternates in direction at a frequency (q.v.) which depends on the speed at which the loop is rotated, and varies in magnitude in a manner which is controlled by the way in which the flux-density varies, that is, the flux waveform. In a practical alternator, steps are taken to ensure that the generated e.m.f. varies in a sine-wave form such as is illustrated under ALTERNATING CURRENT.

It is evident that one cycle of the alternating e.m.f. corresponds to one revolution of the loop. In a multipolar machine the poles are alternately north and south so that one cycle is obtained when the loop moves through an angle corresponding to two pole pitches (see PITCH). The relation between speed and frequency is given under SYNCHRONOUS SPEED, and because of this relation the alternator is a synchronous machine.

To obtain any reasonable output the armature must contain a number of coils connected in series which, because they cannot all be in one place, must be distributed round the rotor or stator. Consequently the e.m.fs. in the coils all reach their maximum value at different instants and their sum has to be obtained vectorially (see ALTERNATING CURRENT) and not by multiplying the e.m.f. per coil by the number of coils.



Simplified diagram illustrating the main principle upon which all generators operate: rotation of a loop of wire in a magnetic field produces an e.m.f.

If the simple machine shown in the diagram had three separate loops instead of one, all having a common axis of rotation, but spaced 120 deg. apart, then the e.m.f. in number 2 would reach its positive maximum one third of a revolution after the maximum in number 1. That in number 3 would occur one third of a revolution later still.

The vectors representing the three e.m.fs. would be equal in length and inclined at 120 deg. so that the machine would be an elementary three-phase alternator.

ALTIMETER. An instrument which measures the altitude of an aeroplane. It does this by measuring the air pressure at the altitude at which the aeroplane is flying, and is thus similar to a barometer in its function. Air

pressure decreases with altitude according to known laws. The instrument consists of a case containing a sealed capsule made of corrugated metal from which the air has been exhausted. The pressure of the air in the case is kept equal to that of the surrounding air by connecting it to the static or closed tube of the pitot head. The air pressure tends to collapse the sealed capsule but is prevented from doing so by a spring. The capsule expands and contracts as the air pressure is varied; its movement is magnified and transmitted to the pointer of the altimeter.

ALTITUDE. Height above mean sea level. The true altitude of an aircraft is sometimes called the tape line altitude. If atmospheric conditions are standard, the altimeter indicates the tape-line or standard altitude. On the other hand, in a non-standard atmosphere, the altitude indicated on the altimeter is the height in the standard atmosphere where the pressure is the same as that of the observed non-standard conditions. This altitude is known as the equivalent pressure altitude.

For correcting aircraft performance to standard atmospheric conditions it is sometimes necessary to use another form of altitude, the equivalent density altitude, i.e., the height in the standard atmosphere where the density is equal to that of the observed non-standard conditions.

ALUM. A double sulphate of alumina and potassium soluble in water. A very small quantity may be added to glue size or flour paste to liquefy the gel without impairing its adhesive qualities.

ALUMINA. The trioxide of aluminium. It is the base upon which the dye-stuffs of artificial lake pigments are fixed. Ground in water, alumina is semi-transparent, but becomes opaque when the water evaporates; in contact with oil it is practically transparent. Consequently, such a lake pigment when used with a water medium becomes much lighter in tone and opaque (ground-obscuring) as it dries, whereas the same pigment used with an oil medium obtains its full colour value only when placed upon a white ground and remains transparent when dry.

ALUMINIUM (Al). Atomic no. 13; atomic wt. 26·97; a bluish-white metal forming about 7 per cent of the earth's crust; density 2·7; M.P. 659·8 deg. C; B.P. 1800 deg. C.; it is not found in the free state, but exists abundantly as silicates, and is a constituent of most common rocks other than limestone and sandstone. The metal is largely used for domestic utensils and its alloys are used extensively in the manufacture of aircraft.

Aluminium, known in the U.S.A. as Aluminum, is trivalent, and forms many important compounds. Aluminium oxide (alumina), Al_2O_3, occurs in nature as corundum and emery, both used as abrasives. Aluminium sulphate, $Al_2(SO_4)_3$, is used in the paper industry, in the purification of water, in tanning and in dyeing. Ordinary alum is a double sulphate of potassium and aluminium containing 24 molecules of water, K_2SO_4, $Al_2(SO_4)_3$, 24 H_2O; it is used in medicine as an astringent. Another variety of alum has ammonium sulphate instead of potassium sulphate. Ordinary clay is a hydrated silicate of aluminium.

Aluminium is manufactured to-day mainly from bauxite and cryolite. Bauxite is a hydrated alumina, Al_2O_3 2 H_2O, found in France, Germany, Rumania, India and British Guiana. Cryolite is a fluoride of sodium and aluminium, Na_3AlF_3, found in Greenland. The alumina content of the bauxite used varies from about 48 to 60 per cent. Ores of lower alumina content are not at present considered economical, although various processes for extraction of alumina from clays, shale and the like have been patented. Thus, the extraction of alumina of high purity, i.e., containing not more than about 0·1 per cent of impurities, is the first stage in the process.

The oxide of aluminium (Al_2O_3) cannot be reduced by the usual agents, and it is necessary to electrolyse a solution of alumina in molten

cryolite in order to obtain the metal, which, in the process, absorbs some impurities, mainly iron and silicon, from the anodes, electrolyte and alumina. The aluminium produced is normally of about 99·3 to 99·75 per cent purity, but a purity above this figure can be obtained by very careful choice of materials. More recently other methods have been perfected whereby aluminium of up to 99·998 per cent purity can be obtained.

The chief characteristics of aluminium are lightness, ductility, electrical and thermal conductivity, and strong resistance to oxidation and attack by many reagents. The specific gravity of the manufactured metal (about 2·6) varies according to whether it is rolled into bars, rolled in sheets or cast. Its ductility is such that it can be beaten into sheets as thin as 0·000025 in. or drawn into wire only 0·004 in. in diameter.

Although it is a good conductor of heat and electricity, it is non-magnetic, and is so soft that it can be readily cut with a steel-bladed knife, the ease with which this can be done forming a rough measure of the hardness. Surface hardening, however, can be produced to a notable degree by mechanical operations such as drawing or cold-rolling until a hardness almost equal to that of brass is attained. The ultimate tensile strength of annealed aluminium of 99·97 per cent purity is about 4 tons per sq. in., and the corresponding figure for 99·0 per cent purity about 6 tons per sq. in. These can be increased by about 80 per cent by cold-working. The annealing temperature varies with the degree of purity, but for metal of a purity of 99·0 to 99·5 per cent recrystallization is complete within a few minutes at 350 deg. C.

ALUMINIUM ALLOYS. Aluminium may be alloyed with a number of metals including copper, nickel, silicon, manganese, magnesium and zinc. With these metals, used either singly or in combination, a great variety of different alloys have been developed.

By the process of adding one of these metals to aluminium to the extent of from 2 to 8 per cent, the tensile strength of plates and bars can be raised to between 40,000 and 50,000 lb. per sq. in., the elastic limit to between 55 and 60 per cent of the ultimate tensile strength, and the elongation to 20 per cent on a 2 in. gauge length, with a corresponding reduction in area of 25 per cent. Yet the alloying element will have raised the specific gravity of the alloy only to between 2·8 and 2·85, as compared with 2·6 for aluminium.

The choice of an alloy for a given duty depends not only on the properties required but also on the method of fabrication to be employed, some alloys being most suitable for casting, others, for forging, and so on. The best known of all aluminium alloys is duralumin (q.v.), which contains 4 per cent of copper, 0·5 per cent of manganese, 0·5 per cent of magnesium and 0·5 per cent of silicon. This, the the first heat-treatable alloy to be discovered, still remains the most popular material of its class. In the fully hardened state, its tensile strength is about 28 tons per sq. in., but it may be readily softened to enable pressing and forming operations to be performed. Duralumin, like many other alloys, will not stand exposure to severely corrosive conditions. Anodizing is the method usually adopted for protecting aircraft components.

A recent novel development is the manufacture of duralumin sheet covered on each face with a thin layer of pure aluminium, this material combining the high corrosion-resistance of aluminium with the strength of duralumin. Some aluminium alloys are very resistant to corrosion. Thus Birmabright, a manganese-magnesium type alloy, may be used for the construction of lifeboats, ships' hulls etc. The alloys used for the manufacture of forgings are in general similar to those employed for sheet, rolled sections etc.

Cast aluminium alloys are used for a variety of different duties. An alloy containing 10 to 13 per cent of silicon is employed for castings which have

to resist corrosive conditions. Y alloy, containing 3·5 to 4·5 per cent of copper, 1·8 to 2·3 per cent of nickel and 1·2 to 1·7 per cent of magnesium is used for pistons for internal-combustion engines.

Aluminium alloys are remarkable for their high strength-to-weight ratio. Thus duralumin in the heat-treated state is almost as strong as mild steel but is less than one third as dense.

ALUMINIUM-COPPER ALLOYS. Aluminium-copper alloys have been developed with a view to preserving the essential lightness and ductility of aluminium while increasing its hardness, tensile strength and rigidity.

Aluminium-copper alloys are of two main classes: (1) those containing from 2 to 10 per cent of copper, the balance being aluminium; and (2) those containing 3 to 10 per cent aluminium, the rest being copper. The former are either rolled into bars or used as castings; the latter, because of their high copper content, are generally known as aluminium bronzes. See DURALUMIN.

Class (1) alloys will have a tensile strength of 43,000 to 56,000 lb. per sq. in., according to the percentage of copper; in manufacture they are poured at the lowest possible temperature into chilled moulds in order to prevent separation of the constituent metals.

Class (2) alloys are notable for their great mechanical strength, hardness and ability to resist corrosion. The composition of aluminium bronze is similar to that of ordinary tin bronze, save that the tin is replaced by aluminium. In addition, proportions of iron, nickel and manganese may be present.

For example, the British Admiralty Aluminium Bronze contains 8 to 11 per cent aluminium, 3 per cent iron, and up to 3 per cent nickel. This alloy is suitable for both sand and die castings. It is extremely resistant to corrosion and has a beautiful golden colour. The main difficulties experienced with the alloy are due to dross formation in melting. Aluminium oxidizes easily and its oxide is insoluble in most fluxes. To avoid oxide inclusion, quiet pouring and efficient dross traps must be employed. Aluminium bronzes may be either wrought or cast, and the ultimate strength may be as high as 80,000 lb. per sq. in. These alloys have good qualities as bearing metals, and may be heat-treated in much the same way as steel.

ALUMINIUM PAINT. A protective coating for metals to prevent oxidation. The aluminium is prepared as bronze, a powder-like substance consisting of minute flakes; this is mixed with a liquid drying medium which may be cellulose in solution or a type of oil varnish made to stand heat.

Paint may be applied by brush or spray to the clean metal surface. An alternative method is to coat the metal or other surface with a fixative, usually japanners' gold size; when this is partially dry and tacky, the bronze is dusted on to the surface with a dabber or hare's foot. Aluminium is a standard finish for hot water pipes and radiators left exposed to view, the metallic finish harmonising with most colour schemes. For decorative purposes it is prepared in leaf form, the normal size being 5 in. square; these sheets are assembled in tissue paper books containing 25 leaves.

Surfaces of this kind which are to be metalled are prepared by painting until they are non-absorbent; upon these japanners' gold size is extended as a film. When this film is partially dry but still tacky, the leaves are laid upon it and pressed into contact with a soft pad of cotton wool. Upon large plane surfaces, the laying must be regular because the joining of the leaves develops a pattern which is a characteristic of this treatment.

AMETHYST, see QUARTZ.

AMMETER. An instrument for measuring an electric current, which normally uses the magnetic or thermal effects to move a pointer across a scale. Various types are dealt with under separate headings according to their

principle of operation. See MOVING-COIL INSTRUMENT and MOVING-IRON INSTRUMENT.

AMMONIA (NH_3). A colourless gas, readily liquefied by cooling or compression. It is very soluble in water, the saturated solution at 15 deg. C. containing nearly 37 per cent of NH_3. Ammonia unites with water, forming ammonium hydroxide, NH_4OH, a weak base.

Ammonia is widely obtained in the distillation of coal in gas works, and is recovered as ammonium sulphate. It is also obtained on a very large scale by the Haber process: nitrogen from the air is mixed with hydrogén obtained from water in the proportion of three volumes of hydrogen to one of nitrogen, and compressed to 150 atmospheres (about 1 ton per sq. in.) and passed over a catalyst of iron and molybdenum at 500 deg. C. The ammonia formed is condensed by cooling.

Ammonia thus made is utilized to a large extent in the manufacture of nitric acid and nitrates. Many of the compounds of ammonia are of industrial importance. What is commonly known as sal volatile or ammonium carbonate, as it is obtained commercially, is a combination of ammonium hydrogen carbonate and ammonium carbamate, NH_4HCO_3, NH_2COONH_4, obtained by heating a mixture of chalk and ammonium chloride or sulphate. It is used in baking powder, in dyeing, and medicinally. Ammonium chloride, NH_4Cl (sal ammoniac), a white solid, is obtained from the ammoniacal liquor of gas works, the ammonia of this being passed into hydrochloric acid and the ammonium chloride crystallized out. It is used in galvanizing, as a flux, in dyeing, and in the manufacture of Leclanché and dry electric cells.

Ammonium hydrogen carbonate, NH_4HCO_3, is used in baking powders. Ammonium nitrate, NH_4NO_3, a white crystalline solid, is an important fertilizer, and an ingredient of several powerful explosives. Ammonium sulphate $(NH_4)_2SO_4$, is a colourless, crystalline solid, soluble in water, and is obtained from the ammoniacal liquor of gas works and from synthetic ammonia by absorbing the gas in sulphuric acid. It is one of the most important fertilizers, and more than three million tons of it are manufactured annually. See COAL.

AMMONIUM SULPHATE, see FERTILIZERS.

AMORTISSEUR, see DAMPING WINDING.

AMPERE. Symbol: A. Customary abbreviation: amp. The practical unit of electric current. It is defined as the curent which deposits 0·001118 gm. of silver per second when silver nitrate is electrolysed. A current of 1 ampere flows when a potential difference of 1 volt is applied to a resistance of 1 ohm. See INTERNATIONAL UNITS OF ELECTRICITY and OHM'S LAW.

AMPERE-HOUR. Symbol: Ah. The practical unit of quantity of electricity. Ampere-hours are given by the product of the current in amperes and the time in hours during which the current flows. Thus one ampere flowing for one hour equals one ampere-hour. See COULOMB.

AMPERE-SECOND, see COULOMB.

AMPERE-TURN. A unit of magnetomotive force. The product of current in amperes and the number of turns of wire through which it passes gives the number of ampere-turns.

AMPLIFICATION. The process of increasing or magnifying alternating voltages or currents. Most voltage amplifiers and small *power* amplifiers operate on the linear portion of the valve's characteristic curve with a view to keeping distortion as slight as possible. These are called Class A amplifiers. Where large power output is required, the relative inefficiency of the *Class A* system gives way to *Class B*. Here two valves are used in *push-pull* (q.v.) under individually distorting but efficient conditions. By proper arrangement, the separate distortions combine so as to cancel out while the efficiency is maintained.

A still more highly efficient amplifier is one operating under *Class C*

conditions. In this case, the distortion is such that it can be used only for radio frequencies in conjunction with a tuned circuit. The natural "fly-wheel" action of the latter is able to select the desired frequency from the complex wave-form.

AMPLIFICATION FACTOR. A radio valve constant. It may be defined as the ratio of a small change of anode voltage to a small change of grid voltage to produce the same change of anode current. Symbol: μ See RADIO VALVE.

AMPLITUDE. The maximum value in either positive or negative direction of an alternating current or voltage; the peak value or crest value of a wave.

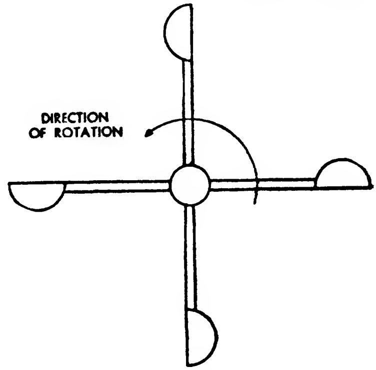
AMPLITUDE DISTORTION. Distortion occurring when the output of an amplifier or radio valve does not maintain proportionality to the input. It introduces harmonics, i.e. frequencies which are equal to multiples of the input frequency. See DISTORTION.

AMPLITUDE MODULATION. The system of transmission most commonly used for broadcasting, in which the music or speech frequencies modulate, or regulate, the amplitude of the radio-frequency carrier wave. See MODULATION.

ANCON. A carved ornament in the form of a bracket under the cornice to a door or window opening, often called a truss or console. Also, a right-angle projection at the top of a vertical architrave, and referred to as an elbow or ear.

ANEMOMETER. An instrument used for measuring wind velocity. Two types are common, (a) cup type and (b) rotating vane type.

The cup type, shown in Fig. 1, consists of four hollow hemispherical cups mounted on arms of equal length, the assembly being free to rotate on a vertical spindle, as shown in the diagram. The wind exerts a greater force on the cup which has its open end facing the wind than on the opposite cup; the difference in these forces causes the assembly to rotate. Means are provided for measuring the speed of rotation, from which the wind speed can be deduced. The



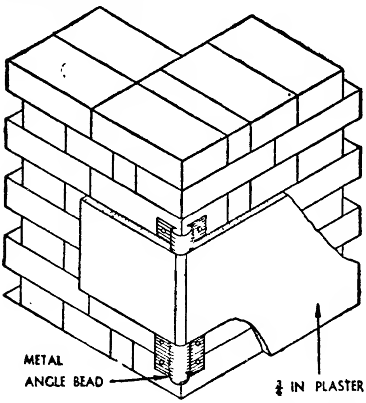
Plan view of a cup-type anemometer which is a device widely used to measure the speed of the wind.

rotating-vane type of anemometer has a multi-bladed fan free to rotate on a spindle. This type has to be held with the axis of the fan in the direction of the wind. The fan is driven round by the wind and the wind speed is deduced from the speed of revolution.

In engineering, the term anemometer is applied to an instrument employed in connexion with the measurement of the rate of flow of gases generally. This instrument may be operated either electrically or by mechanical means.

ANEROID BAROMETER. A barometer working on the vacuum principle. A thin cylindrical metal base, exhausted of air, records the changing pressure of the air outside it by means of a series of levers; these magnify the small movement of the metal covers at each end of the cylinder, which tend to be compressed, or forced inward, by higher pressures, and to expand as the pressure decreases. The usefulness of this type of barometer is considerably enhanced by its easy portability. See ALTIMETER.

ANGLE BEAD. A moulding used to reinforce the external angles of plastered walls. It may be made of wood or metal, and is usually fixed vertically over the intersection of two wall surfaces. The sharp angle at the intersection is thus rounded off to suit the finish required. Metal beading is preferable to wood, and as the leaves

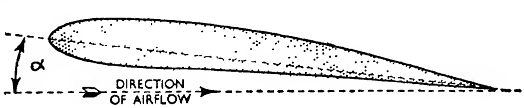


Simple example of the use in building of metal angle beads. Fitted in this way to corners, they provide protection and support for the plaster work.

of such beads are perforated, easy fixing to the brickwork may be obtained and a good key provided for the plaster.

ANGLE JOINTS, see JOINTS.

ANGLE OF ATTACK. In aero. engineering, the angle between the aerofoil chord line and the direction of airflow as indicated on the accompanying diagram. It is varied in flight by means of the elevator controls. Usually denoted by the Greek letter α.



Consideration of the angle of attack is vital in the construction, erection and alignment of the main planes of an aeroplane.

ANGLE OF DOWNWASH. In aero. engineering, the angle through which a current of air is turned on passing over an aerofoil. When air flows over an aerofoil and produces a lifting force on it, the aerofoil is exerting an equal and opposite force on the air. This force deflects the air downward so that it leaves the aerofoil in a different direction from that at which it met the aerofoil. The angle of downwash is usually denoted by the Greek letter ϵ.

ANGLE OF INCIDENCE. In aero. engineering, the fixed angle between the aerofoil chord line and the fuselage datum line as indicated in the diagram on opposite page. It is sometimes erroneously called the angle of attack, q.v.

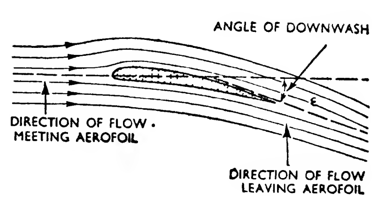
ANILINE INK. A usually liquid and volatile printing ink, which dries almost at once on making contact with the paper. Drying may be accelerated on non-absorbent stocks by passage through a gas flame. Aniline inks are used in connexion with rubber blocks, but other blocks can be used with a slightly more viscous ink. They consist of a dye dissolved in spirit and bound with shellac or a similar resin; modern improvements have evolved an almost complete range of hues. Inks can be made for ordinary paper which dry partly by absorption and partly by evaporation; a marked increase in brilliance is thus obtained. Gold and silver aniline inks are particularly successful.

ANILINE, see BENZENE.

ANION, see ELECTROLYSIS.

ANNEALING. A process involving the heating, followed by the relatively slow cooling of metals, in order to effect changes in their physical properties. The changes aimed at may be: (a) refinement of crystalline structure; (b) softening of the metal to facilitate machining operations; (c) removal of stresses; and (d) the modification of the ductility or magnetic properties of the material.

In sheet-metal work annealing is



Angle of downwash is the extent by which air is deflected by an aerofoil.

used mainly to restore ductility after cold working. For best-class work both time and temperature are critical in this operation, since under-annealing will mean that the required properties are not restored, while over-annealing (temperature too high or time too long) will result in coarse, large-grained metal that will not withstand subsequent forming. The simplest form of annealing is given in the steel-rolling mill and is otherwise known as softening; in this case the rolled sheets are charged straight into a suitable furnace, while hot, from the mill floor, heated to bright red—the temperature not being critical—and allowed to cool in air.

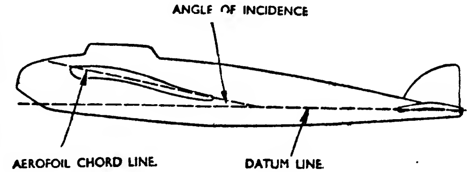


Diagram illustrating angle of incidence. Note that in level flight datum line is horizontal.

Thus, true annealing is much more precise, as in normalizing; in modern normalizing furnaces there are pre-heating, soaking and cooling chambers, the sheets being carried through on a walking-beam conveyor. This type of conveyor is free from pick-up and pitting of the sheet surface. The fuel which is used in these furnaces may be washed producer gas, blast-furnace or coke-oven gas, the combustion air entering through small holes in the furnace crown and the gas at the sides of the furnace under the roof.

The combustion air is thus kept away from the metal surface; the sheets are entirely surrounded by flame and uniformly heated, scale-formation being reduced to a minimum.

Bright annealing processes have also been developed for steel sheet and strip, also for the non-ferrous metals, and these are capable of giving a clean, scale-free surface and economizing in pickling costs. Materials which work-harden readily must, if they are to be subjected to severe deformation, be given inter-stage anneals in order that sufficient ductility shall be restored for subsequent work to be accomplished without failure. Examples of the temperatures usual for inter-stage annealing some non-ferrous metals and alloys are: aluminium 350 deg. C.; aluminium alloys 350 to 400 deg. C., depending upon the alloy additions; brass 500 to 600 deg. C., the exact temperature, again depending upon the metal content being of vital importance. See also CLOSE ANNEALING and NORMALIZING.

Articles to be annealed are usually placed in a box of cast-iron and packed around with substances which have been found in practice to give the effect required, such as sand, fireclay, slaked lime, charcoal, and charred bone or charred leather. The box is then placed in a furnace and brought to the requisite temperature, about 1650 deg. F. for low-carbon steel and 1400 to 1500 deg. F. for high-carbon steel, at which it is kept just long enough for the heating to penetrate throughout the whole contents of the box.

When the heating is completed, the box is withdrawn from the furnace and the contents allowed to cool at a sufficiently slow rate to avoid any hardening. To prevent oxidation of the surface of the articles, air should be excluded as much as possible during all stages of the process.

Process annealing is a term limited to heating below the critical temperature. This method is much used by the wire and strip industries. Annealing is also employed on alloys that possess no critical temperature to soften material previously work-hardened.

In this case, however, the correct temperature to employ is a matter of experience, and no indication of a suitable temperature is given by the

equilibrium diagram of the alloy in question.

ANODE. The electrode at which an electric current enters a liquid, as in electrolysis, or a gas, as in a mercury-vapour rectifier (q.v.). In radio, the term denotes the positive pole, or electrode, of a thermionic valve and it is the electrode to which the electrons emitted by the cathode are attracted.

ANODIC TREATMENT. A process sometimes called *anodizing*, used to improve the corrosion-resisting properties of aluminium and its alloys. The corrosive resistance of aluminium is largely dependent on the formation of a skin of aluminium oxide on its surface which tends to prevent further corrosion.

It is possible for such films to form naturally, but thicker and more durable films can be formed by oxidation of the metal in a bath consisting of sulphuric, chromic or oxalic acids. The article, after previous cleaning, is made the positive pole or anode in the acid bath and a current applied.

As the film develops, the electrical resistivity of the bath increases, so that to maintain the current it is necessary to increase the applied potential from 3 to about 50 volts. Films prepared in this way are extremely resistent to abrasion and corrosion. They are, however, to some extent porous. Complete protection can be afforded by treatment of the film with lanoline or varnish to close the pores. The aluminium oxide in these films readily absorbs dyes and some beautiful colour effects can be obtained by this means.

Anodizing is the most common form of protective treatment used on the duralumin components of an aircraft.

The parts to be specially treated are immersed in a bath containing a solution of 3 per cent chromic acid in distilled water, and the temperature of the bath is maintained at 40 deg. C. A direct current is passed through the bath, the part to be treated forming the anode, while the cathode consists of a carbon plate of the same surface area as the part to be treated.

ANODIZING, see ANODIC TREATMENT.

ANTENNA, see AERIAL.

ANTHRACITE, see COAL.

ANTICER. A device for the prevention of ice formation on the surfaces of an aircraft. One type of anticer possess air which has been heated by the engine exhaust through the leading edges of the wing.

ANTIMONY (Sb). Atomic no. 51; atomic wt. 121·76; a bluish-white metal, Sp. Gr. 6·71, M.P. 630 deg. C., B.P. 1380 deg. C. It is a trivalent or pentavalent element, and forms a number of important compounds such as the oxides Sb_2O_3, Sb_2O_4, and Sb_2O_5; the trioxide Sb_2O_3 is used as a pigment, the trisulphide Sb_2S_3 is used in the manufacture of some fireworks. Antimony forms a component of many alloys, e.g., type metal, Britannia metal, pewter, and various bearing metals. The double tartrate of antimony and potassium, $KSbOC_4H_4O_6.\frac{1}{2}H_2O$, is a valuable drug known as tartar emetic.

ANTIMONY OXIDE. A dry soft white pigment, used mainly in the manufacture of white oil paints and enamels, sold ready for use.

ANTI-SET-OFF SPRAYER. A device, used in the printing trade, for preventing the adhesion of the wet printed impression to the back of the next sheet (see SET-OFF). Several types of sprayer are available, but the principle is the same in all cases. A controlled air stream is blown under pressure through a spray-gun nozzle and made to combine with a special solution which is sprayed as a film cloud.

This film becomes atomized as it settles upon the sheet, and the solid globules separate the succeeding sheets from the previous ink film during the initial setting. The mix was formerly of wax, but is now more usually a resinous base. There is no interference with subsequent printings, for infinitely small quantities are effective. The nozzles of the spray-gun are arranged over the delivery

tray of the machine and both the direction and quantity of the mix are closely controlled, so that local or general application can be made to the sheet. Intermittent control can be either electrical or mechanical. Portable units are available for occasional use and for use where machines of an entire battery need to be equipped; compressed air may be obtained from a central supply and the mix from individual gravity feeds.

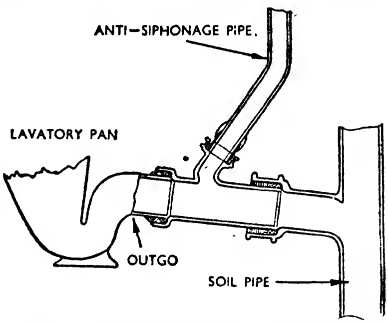


Fig. 2. Anti-siphonage pipe fitted to outgo of lavatory pan in order to maintain the essential water-seal.

ANTI-SIPHONAGE. A system of ventilation pipes designed to prevent the loss of water-seal by compression or siphonic action on the discharge side of any plumbing layout. When waste water is discharged through a trap (Fig. 1a), a vacuum is set up in the waste or soil pipe which tends to empty the trap by siphonic action. Conversely, the descent of waste water or sewage in a soil pipe (Fig. 1b) exerts a certain compression upon the water seal in the traps of fitments at a lower level, which again may cause loss of water seal. Ventilation pipes, properly fitted, will overcome both these tendencies.

Fig. 2 shows an anti-siphonage or branch ventilation pipe fitted by means of a shaped section to the cast-iron outgo of a w.c. pan discharging to a soil pipe. The rule is that the ventilation pipe must be connected to the outgo not less than 3 in. and not more than 12 in. from the crown of the trap in the direction of the water flow. This is to prevent waste matters from the discharge washing up into and possibly stopping up the pipe.

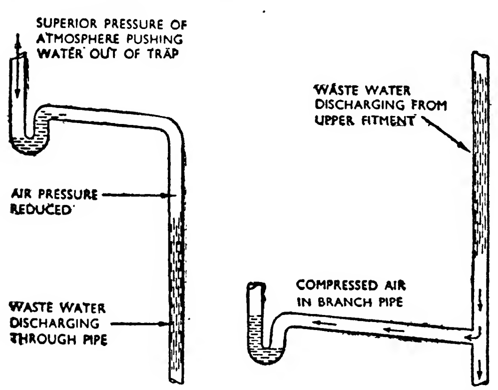


Fig. 1. Diagram showing two instances of how loss of water-seal may occur. In both cases this may be overcome by correctly fitting anti-siphonage pipes.

On next page, Fig. 3 shows lead pipe connexions of anti-siphonage pipes with wiped soldered joints: (A) connexion to horizontal outgo; (b) connexion to vertical outgo.

Anti-siphonage pipes from a series of traps emptying into one main stack, whether on one level or on different floors, should be connected and carried up separate to the stack to a point above the highest discharge connection. From this point the main anti-siphonage pipe can either be connected to the stack or carried up separately to a similar height.

The sizes of anti-siphonage pipes vary from 1 in. to 1½ in. for waste pipes, and from 2 in. to 3½ in. for soil pipes, the latter diameter being for the main anti-siphonage pipe or ventilation pipe to which the various branches may be connected. The main anti-siphonage pipe must in all circumstances be continued down-

wards and then joined to the soil pipe below the point of the lowest branch connexion. The provision is that where the vertical distance between the lowest branch discharge pipe connexion and the invert of a horizontal drain pipe is less than 10 ft., the main ventilation pipe must be connected to the soil pipe at a point not less than 9 in. and not more than 2 ft. below the lowest branch connexion.

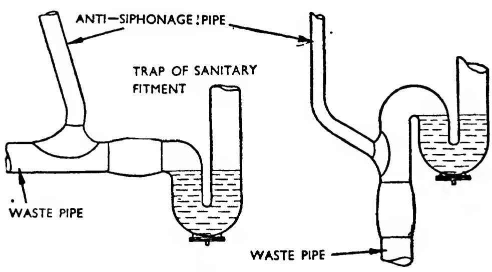


Fig. 3. Anti-siphonage pipes as often fitted on the waste pipes of sanitary appliances.

Materials for anti-siphonage or ventilation pipes may be the same as for soil and waste pipes.

ANTWERP BLUE, see PRUSSIAN BLUE.

APERIODIC. Not periodic. A term applied to a varying quantity that does not repeat its values at regular intervals of time, but which progresses towards a stable condition.

APERIODIC CIRCUIT. A circuit which is not tuned to any particular period, i.e., frequency. Circuits which would otherwise be oscillatory are readily made aperiodic by the inclusion of suitable values of resistance.

APPLETON LAYER, see IONOSPHERE and RADIO-WAVE PROPAGATION.

AQUATONE. A superfine method of making printing plates for lithographic offset printing first devised by Robert John about 1923. It has since undergone modifications, and is now carried out as follows :

A normal lithographic metal plate is grained very finely, counter-etched, warmed and coated with gelatine solution which dries out to a film 0·0002 in. in thickness. As gelatine is a reversible colloid, i.e., it melts on heating and re-solidifies on cooling, the dried film is treated with a solution of formaldehyde in alcohol, and thus becomes an irreversible colloid. The film will not now melt with heat, but will absorb water. When the treated film is dry it is baked for about ten minutes at 200 deg. F.; a solution of potassium bichromate is then applied and the gelatine film becomes saturated; when dry, it is light-sensitive. Exposure is then made through a photographic half-tone negative, either in a hand or mechanical printing-down frame, and the film is hardened selectively and developed in cold water. The hardened sections are now ink-attractive and not water-attractive. No further treatment is given to the plate, which is now ready for the offset machine.

ARC. In electrical engineering, a term meaning a visible electrical discharge through a gas which is in a conducting condition. The voltage across it is usually low and the current carried is comparatively high. The arc normally causes burning of the contacts or electrodes between which it plays. See ARC WELDING.

ARCH. A mechanical arrangement of wedge-shaped blocks placed over an opening in such a manner that each block supports the other by mutual pressure, combined with an efficient opposition to its thrust.

Arches are classified according to their form. The chief are as follow:

(1) *Segmental,* the curve of which is a part of a true circle ;
(2) *Semi-circular,* the curve being one half of a true circle ;
(3) *Elliptical,* the curve being a portion of an ellipse ;
(4) *Pointed,* of which there are several variations.
(5) The *flat* arch.

The curves of a pointed arch are formed by striking arcs from two

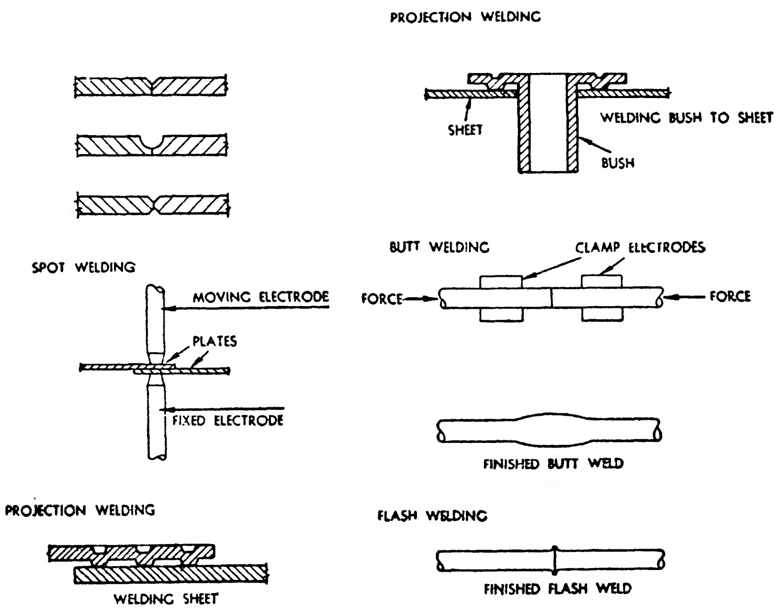
independent centres so that the curves at the crown of the arch meet at a point. Pointed arches belong to the various periods of Gothic architecture.

ARCHITRAVE. In architecture, the lowest of the three principal parts, viz. *architrave*, *frieze* and *cornice*, comprising what is known as the entablature, and which is supported upon columns. In joinery, the marginal band enclosing an opening or the surround of a doorway or window opening. It may be moulded or plain, its angles being mitred. Its chief function is to cover the joint between the door frame or linings and the grounds, also the joint formed by the junction of the plaster and the grounds. The lower ends of an architrave usually finish on top of wood blocks known as "plinth blocks".

ARCING CONTACT. Auxiliary contact on an electrical switch to which the current is transferred before the flow is finally broken. Its object is to save wear of the main contacts due to arcing and it is easily replaceable.

ARC SPECTRUM. The spectrum obtained from the examination of the light emitted by a substance heated in an electric arc; the arc spectrum usually contains fewer lines and less intense ones than the spectrum obtained from the same substance heated by an electric spark.

ARC WELDING. A method of welding in which the work to be welded is heated by an electric arc, which may be struck from a carbon or a metallic electrode. In the former case, the carbon electrode is followed up by the use of metallic fillers which are fed into the joint to be welded. Thus, not only is the parent metal fused, but additional metal is deposited in the joint. In shielded carbon-arc or metallic-arc welding, the molten filler and weld metals have to be protected from the action of the



PREPARATION FOR VARIOUS KINDS OF ARC WELDING

Various ways of arranging sheet metal for welding. Also shown are finished butt and flash welds. A butt weld is suitable only when the plates are relatively light.

atmosphere. The energy is supplied by either direct or alternating current. The process is best described by considering the welding of two pieces of mild-steel plate. The plates may be prepared in many ways, examples being shown in the illustration; if they are relatively light they may not need preparation, being only butted.

The earth, or negative, terminal of the power supply is connected to the plates, and the other to the welding electrode. The tip of the electrode is touched to the work and withdrawn slightly, forming an arc which renders a portion of the work molten, at the same time depositing molten metal from the electrode. The material of the two plates and that of the electrode fuse together; the inclusion of oxides etc., in the glowing metal is prevented by a covering of brittle slag formed from the covering of the electrode, this slag being easily chipped-off when the weld has cooled. This process is essentially one of adding molten metal, and differs from most other welding operations in that no pressure is applied to the joint.

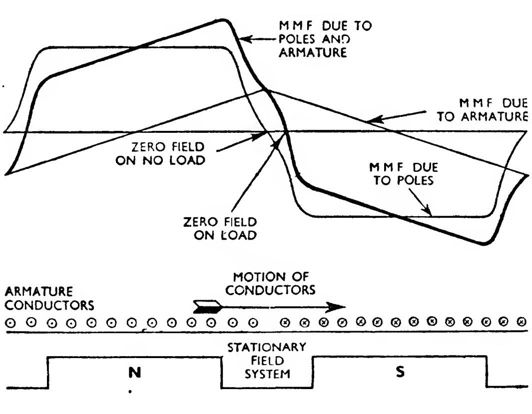
Automatic arc-welding machines are now much used for welding long uninterrupted seams on metal pipes, boilers or tanks; they incorporate a device which feeds the metallic electrode at whatever rate may be needed for the maintenance of a constant arc-voltage and length of arc. The feed, which varies in proportion to the diameter of the electrode and the current employed, is derived from an electric motor built into the machine.

AREA (Building). A sunken space around the basement of a building, the purpose of which is to give light and air to the interior. See OPEN AREA.

ARGON (A). Atomic no. 18; atomic wt. 39·944; one of the inert, rare gases of the atmosphere. It is produced in quantity by distilling liquid air and is used for filling electric-light bulbs. It boils at −186·1 deg. C., and melts at −189·6 deg. C.

ARMATURE. The part of a rotating electrical machine in which an e.m.f. is generated. In alternators, this is almost always the stationary part; in D.C. generators and motors it is usually the moving part, while in A.C. motors it may be either. The term is also used to mean the moving part of a contactor, electric bell, or similar electro-mechanical device.

ARMATURE REACTION. The effect upon the magnetic field of an electrical machine caused by currents in the armature. The field is distorted and may also be strengthened or weakened. The amount and nature of the effect depends on one or more of the following: load, power factor, degree of saturation, brush position. The diagram shows the field and armature of a D.C. generator laid out flat, together with the m.m.fs. which they produce separately and together. For approximate purposes the m.m.f



In a D.C. generator, the effect of armature reaction is, as this diagram shows, to distort the field produced by the poles alone and also to shift the position of zero field in the direction of rotation. On no-load, the m.m.f. due to the armature is absent ; on load, its size depends on the current, but the shape remains constant.

shapes may be taken to be the same as the flux shapes.

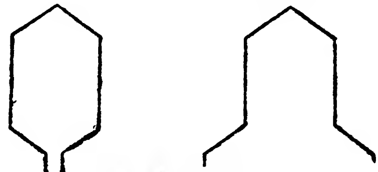
The directions of currents, indicated by dots and crosses, which represent currents out of and into the paper respectively, and of the m.m.fs. may be checked by using the left- and right-hand rules.

It will be seen that the field is distorted and that the neutral point, the point of zero field, is displaced in the direction of rotation.

In the case of a motor, the current is in opposition to the e.m.f. so that the triangular m.m.f. shape is inverted and the neutral point moves backward instead of forward.

Armature reaction in A.C. machines is more complicated because the armature current and e.m.f. may not be in phase with each other and so may combine in any manner from direct addition to direct subtraction.

ARMATURE WINDING. The portion of the armature of an electrical machine which consists of the conductors and the connexions between their ends. Owing to the small e.m.f. generated in one conductor, it is necessary to connect a number of them in series in a practical machine. The art of armature winding is so to connect the conductors together that a mechanically sound and convenient arrangement is secured, which uses a minimum amount of copper. The connexions commonly used in D.C. machines are known as wave and lap windings. A coil for each of these is illustrated in the diagram. See LAP WINDING and WAVE WINDING.



ARMATURE COILS IN

LAP WINDING WAVE WINDING

Lap and wave windings may be recognized by the way in which the end connexions are bent. A lap winding progresses slowly round the armature, whereas a wave winding moves in leaps and goes several times round.

ARRESTER. An electrical by-pass circuit normally connected between an overhead line and earth for the purpose of diverting surges to the latter. The circuit usually consists of a horn gap in series with a special resistor. Synonym: Surge Diverter. See HORN GAP and SURGE.

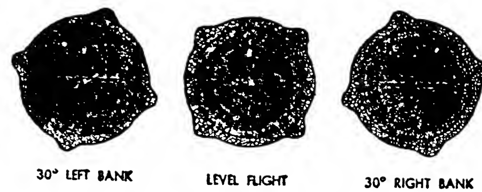
ARRESTER GEAR. A device used on aircraft carriers to reduce the landing run of aircraft. All carrier-borne aircraft are provided with an arrester hook near or under the tail and the pilot lowers this when landing. This hook engages one of a number of resiliently mounted cables stretched across the surface of the deck, and so brings the aircraft to a standstill.

ARSENIC (As). Atomic no. 33; atomic wt. 74·91; a grey, crystalline solid with a metallic lustre; it exists in three different varieties; Sp. Gr. of grey form, 5·73. It sublimes without fusion at 450 deg. C. It is usually trivalent or pentavalent, forming such compounds as the oxides As_2O_3 and As_2O_5 and the chlorides $AsCl_3$ and $AsCl_5$. Among the ores of arsenic are orpiment, As_2S_3, and realgar, As_2S_2. The trioxide, As_2O_3 (white arsenic), is a valuable nerve tonic used in medicine; it is also a cumulative poison. Arsenic tri-iodide, AsI_3, is also a drug; it is a component of Donovan's solution, which contains 1 per cent each of arsenic iodide and mercuric iodide. Dibasic sodium arsenate, Na_2HAsO_4, 12 H_2O, is used in calico printing. Some of the organic compounds of arsenic, e.g., salvarsan, $C_{12}H_{12}O_2N_2As_2$, 2 HCl, 2 H_2O, have also been largely used in medicine. The so-called poison gas, Lewisite, is really a liquid with the formula, $ClCH : CHAsCl_2$. Some of the other poison gases are derivatives of arsine, AsH_3.

ARTIFICIAL HORIZON. An instrument which shows the pilot of an aircraft the angle at which he is flying relative to the ground, under conditions when he is unable to see the horizon. It contains a gyroscope; which may be driven electrically, or is kept spinning about a vertical axis

by a jet of air induced by the suction of the vacuum pump or venturi tube. A horizon bar is connected to the gyro and the pilot can tell the attitude of the machine by the position of the horizon bar relative to that of a small outline of an aeroplane rigidly fixed to the case. If the miniature plane is kept parallel to the bar, the aeroplane will be level laterally.

The illustration gives the indication of the instrument in various attitudes of flight.



Artificial horizon which shows the pilot of an aircraft whether the plane is banking, climbing or gliding, or if it is flying level. The type of indicator illustrated is the Sperry Horizon.

ASBESTINE. A natural form of hydrated magnesium silicate reduced to a fine soft powder. It is used as an extender in paint, and forms the chief pigment in paints made for fire-resisting purposes.

ASBESTOS. A fibrous silicate of magnesium, calcium, sodium, and iron, of which there are several varieties. It melts at 1,280 to 1,310 deg. C., and is a good heat-insulator. When mixed with Portland cement it is used in corrugated sheets and for roofing tiles. It may be woven, when mixed with cotton, into a stiff cloth for brake linings, and other purposes.

ASBESTOS-CEMENT SHEETING. A fire and waterproof material, made from asbestos and cement, supplied in sheets or tiles for building purposes. Plain or corrugated sheet is frequently used for the roofs and walls of small structures, such as garages, and gives good service provided it is not subjected to any great strain or shock. It can be cut to size with an ordinary hand-saw and fastened with clout nails. Small-headed ordinary nails are of little use for the purpose, as they pull through the rather weak asbestos fibres. See ASBESTOS SHEETING.

ASBESTOS SHEETING. Fireproof slabs of material made from asbestos and plaster of Paris used for covering walls and fixed similarly to asbestos-cement sheeting (q.v.). Both these materials are excessively absorbent as well as alkaline, and these characteristics must be kept in mind when they have to be painted. The best results are obtained by applying two coats of a good water paint, thinned only with the petrifying liquid supplied by the makers. Fronts, backs and edges must be coated before the slabs are fixed in position. Upon this foundation, oil paint can be satisfactorily applied after erection.

ASH. A tough, flexible hardwood grown in N. Europe. Used for shafts for striking tools, gymnastic appliances, bentwork etc. Figured wood is used for veneers in cabinet work. Ash is seldom used, however, in carpentry. See TIMBER.

ASHLAR. Finely dressed blocks of stone worked to fit in to the general face of a wall. Ashlar is known by its surface finishing according to the detail required as:

(1) *Plain*, with the faces rubbed, dragged, or polished;

(2) *Rusticated*, with plain faces projecting from the face of the wall, whilst the back of the rustication or

rebate is set flush with the face line of the wall;

(3) *Rock-faced*, with the faces left rough from the pitching tool. The beds and joint surfaces of the stone are worked true; and

(4) *Chisel-drafted*, upon which chisel drafts are worked along the four edges of a face surface, the centre portion of the surface being left rough or worked into various forms.

ASPECT RATIO. The ratio of the span to the mean chord of an aerofoil surface. For wings which are not rectangular in plan form it is more conveniently measured as the square of the span divided by the area.

ASPHALT. A bituminous substance, formed either naturally by the evaporation of the more volatile matter in oil deposits, or artificially in the distillation of crude petroleum. The "asphalt" used in building is a mixture of asphaltic bitumen with a large proportion of crushed stone. Lime and sand are also used in its manufacture. It is prepared in various forms for paving, damp-proofing and roofing. Mastic asphalt is a mixture of asphaltic bitumen with a powdered filler and clean, sharp sand, supplied in blocks which can be heated and smoothed into position with hot irons. It melts at a temperature of about 300 deg. F.

ASTATIC. A term applied to a pair, or other arrangement, of magnets or coils so disposed that the effect of a stray magnetic field on the whole system is negligible.

ASTRO-NAVIGATION. The science of finding one's way from place to place by means of observation of heavenly bodies. It has come into increasing use in air navigation in recent years, as it is especially useful when radio silence has to be maintained and landmarks are rare or invisible.

ASYNCHRONOUS MOTOR. An alternating-current electric motor the speed of which does not depend solely on the supply frequency and the number of poles. An example is an induction motor (q.v.).

ATHODYD. A jet-propulsion engine for aircraft in which the compression of the air is achieved solely by the ram effect of its forward speed. The best-known example of pure jet propulsion is the engine of the German V1 flying bomb.

Such engines, by reason of the low pressure-ratio of the heat cycle are relatively inefficient on the basis of thrust produced per unit of fuel consumed. They have, however, the advantage of light weight and simplicity for use in expendable weapons such as the V1. They are sometimes known as "ramjets."

ATMOSPHERE. The air or gaseous envelope surrounding the earth. It is divided into two parts: (a) the troposphere, the lower part of the atmosphere, in which region the temperature decreases with increase of altitude; (b) the region above, called the stratosphere, in which the temperature is constant. The altitude at which the troposphere and stratosphere meet is known as the tropopause, and varies with climatic conditions from about 28,000 to 38,000 ft. Ordinary dry air contains the following gases:

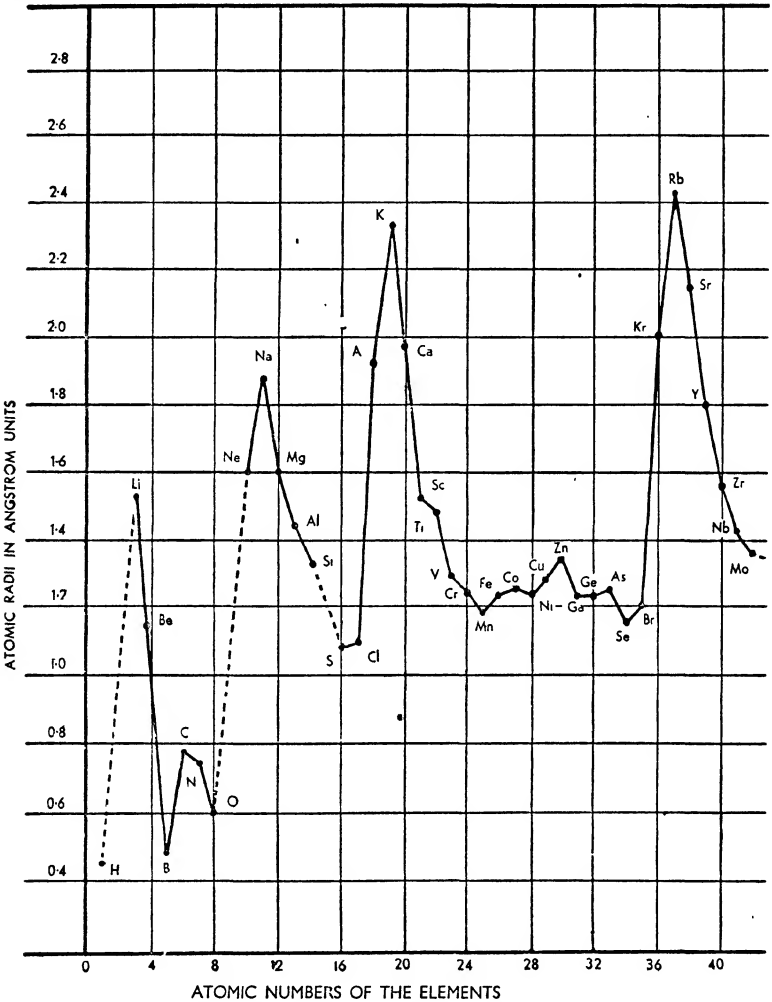
	per cent
Nitrogen	78·08
Oxygen	20·94
Argon	0·9325
Carbon dioxide	0·03
Neon	0·0018
Helium	0·0005
Krypton	0·0001
Xenon	0·000009

It may be liquefied by cooling under pressure, and can be distilled, the more volatile constituents coming away first.

In this manner, oxygen and nitrogen are prepared for medical and other purposes, and argon and neon are prepared in quantity for filling lamp bulbs, neon signs, and so forth.

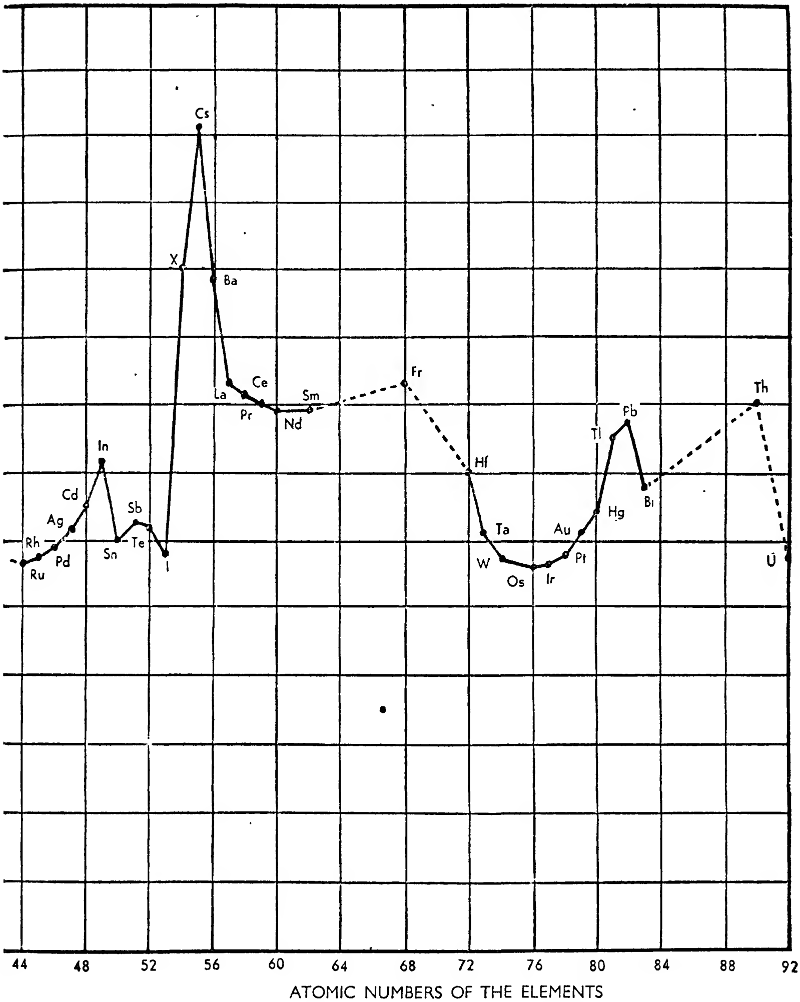
ATMOSPHERICS. Crackles caused in a receiver by radio waves set up by electric discharges in the atmosphere. Also called static or Xs. See INTERFERENCE.

ATOM. The smallest part of an element that can exist and still retain the properties of the element. If an atom is split, the particles do not have



The distances separating the atoms of elements in crystaline form, known as atomic radii, can be readily calculated from certain data. The graph shown here gives

the properties of the element. The atom consists of a small central nucleus round which a number of electrons rotate or may rotate. These are arranged round the nucleus in different orbits or energy levels, and the outermost electrons determine the chemical properties of the element; they do not exceed eight in number. Nearly all the mass of the atom is concentrated in the nucleus, which is positively charged with electricity; each electron is, or is charged with, one unit of negative electricity, and the total charges of the electrons equal the charge on the nucleus, so that the atom as a whole is neutral. The mass of the nucleus of an element appears to be made up partly of matter that is positively charged with electricity, and partly of matter that is not charged; the latter increases the mass



the atomic radii applicable to the main elements, and such information may be used as a basis for calculations concerning the structure of chemical compounds.

of the atom but does not affect its chemical properties. It is therefore possible to have two or three atoms with the same chemical properties but different masses or atomic weights. Such atoms are known as isotopes of the element, and most elements consist of a mixture of isotopes. Thus chlorine is a mixture of two isotopes, one with an atomic weight or mass of 35 and the other with one of 37. The element chlorine has an atomic weight intermediate between these numbers, namely, 35·457. See ELECTRON.

ATOMIC HEAT. The product of the atomic weight and specific heat of an element.

ATOMIC-HYDROGEN WELDING. A process in which the welding heat is generated by passing a stream of hydrogen through an electric arc

between two inclined electrodes, which are usually of tungsten. The high temperature of the arc dissociates molecules of the gas into atoms, a large quantity of heat being absorbed by the hydrogen during dissociation. When the atoms leave the influence of the arc they recombine, forming molecules of hydrogen and liberating heat previously absorbed. The gas then burns in the ordinary way, taking up oxygen from the atmosphere for the purpose.

The average temperature of the flame is approximately 4000 deg. C., which is higher than the maximum temperature of any other flame. The heat is concentrated chiefly at the point of recombination of the atoms, and this recombination is accelerated catalytically by contact with the surface of the metal being welded. Thus an intense flame is obtained at the point of welding. The process is, therefore, used when rapid welding is necessary, as for stainless steels and other special alloys. The hydrogen envelope prevents oxidation both of the metal and the tungsten electrodes, and it also reduces the risk of nitrogen pick-up. The non-oxidizing characteristic is perhaps the most important in practice.

As a rule, the cost of welding by this process is slightly higher than with other processes, but it is sometimes the only practicable method by which a satisfactory weld can be made. An automatic atomic-hydrogen welding process has also been developed in which, instead of using hydrogen from high-pressure cylinders, the hydrogen is obtained by cracking anhydrous ammonia.

ATOMIC NUMBER. The number denoting the place of an element in the Periodic Table (q.v.). The known elements, now 96 in number, can be arranged in a definite order, the simplest element, hydrogen, being No. 1, the next simplest, helium, No. 2, and so on. One of the most complicated is uranium, No. 92. The elements are placed in this order in a Periodic Table in which elements similar to each other in valency and other chemical properties come in the same section of the table. The atomic number of an element also indicates the number of electrons surrounding the nucleus in an atom of the element. The atomic numbers have been confirmed by the X-ray spectra of the elements. See X-RAYS.

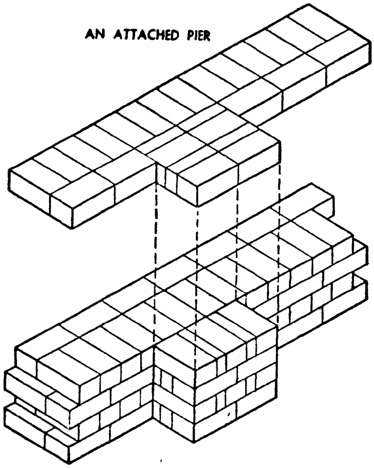
ATOMIC RADIUS. In the crystalline form, the atoms of elements are always situated at definite distances from each other. For instance, in rock salt, NaCl, the distance between the centres of any pair of sodium and chlorine atoms is 3·0 Ångström units. By considering a number of compounds, it is possible to arrive at the radius of each atom (assumed to be spherical), In the instance quoted, the the atomic radii of sodium and chlorine are 1·9 and 1·1 A.U. respectively (1 A.U. $= 10^{-8}$ cm.).

The graph which appears on pages 40 and 41 shows the calculated radii for all the main elements. Since the radii for potassium and iodine are 2·31 and 1·33 respectively, we can calculate that the distance between these two atoms in the potassium iodide crystal, KI, is 3·64.

ATOMIC WEIGHT. The ratio between the weight of one atom of an element and $\frac{1}{16}$ of the weight of an atom of oxygen. It was believed a century ago that the atom of oxygen had a mass or weight sixteen times that of the hydrogen atom, that the carbon atom had a mass or weight twelve times that of the hydrogen, and so on for the other elements then known. The figures 1 for hydrogen, 12 for carbon, 16 for oxygen, and so on, were called the atomic weights.

Subsequent experiments show that such ratios could not in general be expressed by round numbers. During the last twenty-five years it has been proved that most of the elements are mixtures of substances having identical chemical properties but masses or weights that differ slightly.

ATTACHED PIER. Brickwork built out from the face of the wall, in the form of a pier or projection and bonded with the wall brickwork. Many buildings are constructed with



In the construction of attached piers to a brick wall the principles of bonding must be rigidly adhered to as considerable strength is necessary.

comparatively thin walls and upon a system where the loads of the buildings are concentrated at defined points. At such points it becomes necessary to increase the thickness of the walls with an attached pier to form a larger area of wall support for the load.

ATTENUATION. The reduction in the voltage of an electrical surge, which is caused by absorption of energy from it as it travels. The energy absorbed is dissipated in losses such as copper loss. In telephony, the word is given a numerical significance in terms of the input- and output-voltages of a portion of a circuit, such as a cable. See DECIBEL.

AUDIO FREQUENCY. An audible frequency, that is, one appreciated by the human ear. The term "low frequency" is still often used in this connexion.

AUSTENITE. A solid solution of carbon in iron. It is stable only within the ranges of composition and temperature given by the area ADSG of the iron-carbon equilibrium diagram which appears under the heading IRON-CARBON ALLOYS. Austenite is non-magnetic. On cooling below 700 deg. C. it is completely transformed into ferrite (or α iron), which is magnetic, and cementite (Fe_3C), to form the eutectoid pearlite together with free ferrite or free cementite, depending on whether the carbon content is less or greater than 0·87 per cent respectively. On quenching, the transformation is retarded but cannot be prevented in pure iron-carbon alloys. A number of intermediate products are formed. They are martensite (q.v.), troostite (q.v.), sorbite (q.v.) and pearlite (q.v.), formed in order of decreasing rates of cooling. The addition of alloying elements may, however, lower the transformation temperature to such an extent that it is either considerably retarded so that only intermediate products are formed, or may even be entirely prevented. For example, Staybrite steel containing 18 per cent chromium and 8 per cent nickel is completely austenitic at room temperature even after slow cooling. See IRON-CARBON ALLOYS.

AUSTENITIC CAST-IRON. Cast-iron containing such a proportion of alloying constituents (nickel, chromium, copper or manganese) that the structure in the cast state is completely austenitic at ordinary temperatures. This fully austenitic structure can be developed in various ways depending on the characteristics required of the cast-iron. Thus, a high proportion of manganese renders the iron non-magnetic, a high proportion of nickel confers, in addition, great resistance to corrosion and heat. A typical composition for the corrosion-resisting type, developed by the Mond Nickel Co., and known as Ni-Resist is as follows:

Total carbon	..	3·0 per cent
Silicon ..	..	1·5 ,,
Manganese	..	1·0 ,,
Nickel ..	..	14·0 ,,
Copper ..	..	7·0 ,,
Chromium	..	2·0 ,,

Such iron can be made by cupola or crucible melting and, in resistance to corrosion, is as good as, or better than, gunmetal.

AUTOGENOUS WELDING. The union of metallic surfaces by fusion

as a result of the application of intense heat. Although electric welding may be regarded as a special form of autogenous welding, the term is confined in practice to welding in which the necessary temperature is derived from the combustion of oxygen and another gas, usually acetylene or hydrogen. The gases are led to a blowpipe, or torch, in which they mix and burn at the nozzle with intense heat. Additional material in the form of a rod or wire may be used to form the weld by fusing-in between the surfaces to be joined, but this rod is not necessarily of the same composition as the main surfaces. The process has made possible immense savings in time and expense in the fabrication of articles whose components would otherwise have to be riveted or screwed together; it has also an important application in repair work. See ELECTRIC WELDING and OXY-ACETYLENE WELDING.

AUTOGIRO. The patented name for the particular form of *gyroplane* invented by the late Señor de la Cierva. It has now been developed to a state where no fixed wings are required, and the machine can take off without any ground run. The machine is controlled solely by a control stick attached to the hub of the rotor. See GYROPLANE.

AUTOLITHOGRAPHY. The direct drawing on lithographic stones or plates with grease crayons and/or a greasy ink. Such work has a freedom of flow and a virility which is usually lost in photographic copying. This method also encourages a practical knowledge both of the limitations and the possibilities of the process and craft, and thus aids superior artistic interpretation and broader exploitation of the lithographic medium. The grained-stone method attracted many outstanding artists, particularly during the first half of the 19th century—for example Daumier and Goya. Certain contemporary artists are also highly successful in this medium, notably in the field of the poster. See LITHOGRAPHY.

AUTOMATIC BOOST CONTROL. A device built into an aero-engine which automatically adjusts the throttle opening so as to maintain constant the boost pressure at altitudes up to that at which the engine is rated. This relieves the pilot of the duty of constantly adjusting the throttle position during climb or descent.

AUTOMATIC FREQUENCY CONTROL, see TUNING.

AUTOMATIC GAIN CONTROL (A.G.C.). Often, though somewhat incorrectly, called automatic volume control (A.V.C.). This is a system, particularly applicable to superheterodyne receivers, operating on the principle that the signal reaching the

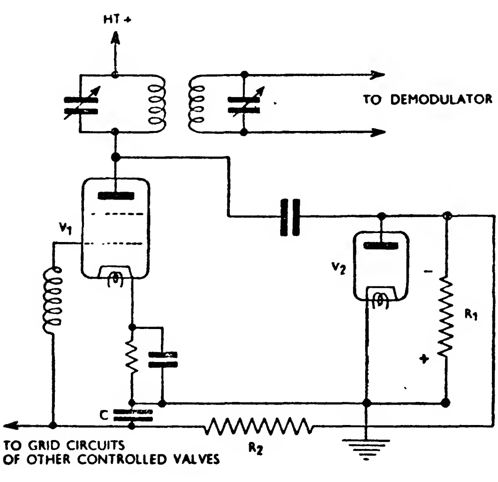
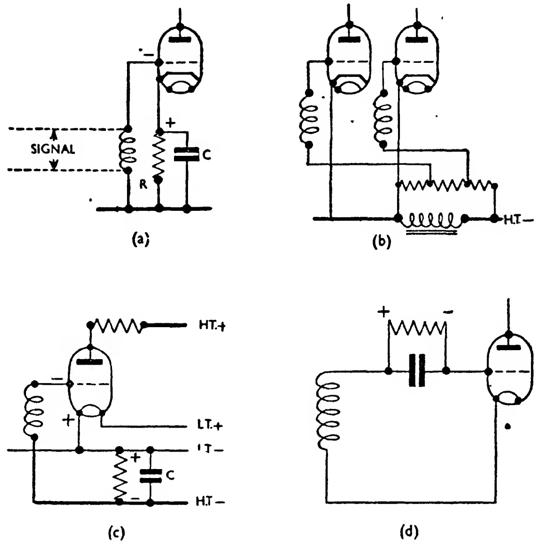


Diagram showing production of automatic gain control voltage. The output of a radio frequency amplifying valve V_1 apart from going to the signal demodulator, is rectified by means of the diode V_2 and a negative unidirectional voltage, depending for its magnitude on carrier amplitude, is developed across R_1. This voltage is "smoothed" by the filter circuit R_2 and C and passed on to the grid circuits of the valves which are to be controlled.

demodulator valve provides, after suitable rectification, a steady voltage which is used as grid bias for the radio frequency amplifiers to reduce their gain. With such a system it is possible to provide the audio-frequency amplifiers of the receiver with a signal whose strength is substantially independent of carrier strength. Automatic gain control therefore, can be exceptionally useful in overcoming the effects of fading and for preventing "blasting" and overloading when tuning to, or through, powerful transmitters in selecting a programme.



Four methods of obtaining automatic grid bias. In diagram (b), by-pass and decoupling condensers have been omitted for the sake of clarity in essential circuit features.

AUTOMATIC GRID BIAS. A system of providing negative grid bias for a valve stage by utilizing the voltage drop across a resistance included in the cathode circuit, or by using the voltage produced across the grid leak in circumstances where the grid may be driven positively. The accompanying diagrams show four methods of obtaining automatic grid bias.

At (a) is shown a means of utilizing the voltage drop across a resistor in the cathode circuit of a valve. This is also known as cathode bias. The purpose of the condenser C is to by-pass the A.C. component of current which is not wanted in the production of a steady voltage.

The voltage drop across a choke or field coil in the negative H.T. supply may be divided, as shown in (b), so as to give the correct bias to several valves.

An automatic bias system applicable to battery-operated receivers, is shown at (c). In principle, the method is similar to that indicated at (a).

In certain radio-frequency oscillators and amplifiers, bias may be derived by driving the grid positive for a short portion of each signal cycle. The grid and cathode act like a diode and the rectified signal voltage appearing across a resistance-condenser combination provides the negative bias. The circuit for this is shown at (d) in the accompanying diagram.

AUTOMATIC PILOT. A device which keeps an aircraft flying straight and level for considerable periods without human aid. It consists of three gyroscopes mounted in gimbals so that each one has its axis parallel to one of the axes of the aircraft. Any disturbance to the straight and level flight of the aircraft causes a displacement of the appropriate gyroscope relative to the aircraft. This displacement causes the appropriate control surface to be moved by electric, hydraulic, or pneumatic power jack which moves the appropriate control

surface, and thus restores the aircraft to its steady flight conditions.

AUTOMATIC TELEPHONY. A system of telephone-exchange operation whereby subscribers are connected to one another as they require, without human intervention.

AUTOMATIC TUNING, see TUNING.

AUTOMATIC VOLTAGE REGULATOR. A device which maintains the terminal voltage of an electrical generator within close limits in spite of fluctuation in the load. This is usually done by using small changes in the voltage, due to variations of the load, to control the amount of excitation in such a way as to restore the voltage to its original value. Some

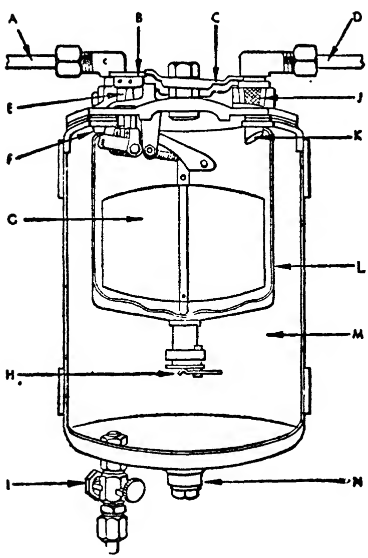


Diagram of autovac showing details of construction. The main components are as follows: *A* induction-pipe and windscreen-wiper connexion; *B* air vent to outer chamber; *C* clamping plate; *D* main petrol-supply connexion; E non-return valve; *F* vent tube; *G* self-draining float; *H* drop valve; *I* carburetter connexion cock; *J* petrol filter; *K* petrol-supply inlet; *L* inner chamber; *M* outer chamber, and *N* plug for draining off sediment.

regulators are electronic while others are electro-mechanical, for example Tirill Regulator.

AUTOMATIC VOLUME CONTROL, see AUTOMATIC GAIN CONTROL.

AUTO-TRANSFORMER. An electrical transformer having part of its windings common to both primary and secondary circuits. Auto-transformers are generally used only when the voltages on the two sides are nearly the same, or when operated intermittently as in induction-motor starting. Variable-ratio auto-transformers are used in testing and laboratory work to provide a variable-voltage supply. See TRANSFORMER.

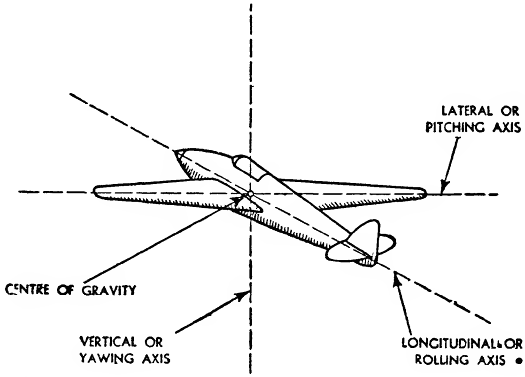
AUTOVAC. A device used on some types of road vehicle to maintain a supply of fuel to the engine when the main fuel tank is situated below the level of the carburettor. The chief components of the unit, as shown in the accompanying diagram are two cylindrical containers fitting one inside the other, their upper ends sealed by a common cover. An outlet pipe connects the outer chamber or reservoir with the carburettor. This chamber is open to the atmosphere through an air vent. The inner or vacuum chamber is connected by pipes to the main fuel tank and the induction pipe. Inside it a metal float operates, by means of a spring action, two valves, one controlling suction, the other air. A third valve at the bottom of the chamber, although normally in a closed position, allows fuel to flow to the outer chamber when the float has risen to a predetermined height.

When the vacuum chamber is empty, the float holds the air valve closed and the suction valve open. Engine suction creates a partial vacuum and fuel is sucked from the main tank. The float rises, closing the suction valve and opening the air valve; the weight of fuel opens the drop valve and fuel passes to the outer chamber.

The cycle is then repeated until the level of the fuel in the outer chamber equals that of the inner; the

float then prevents further suction until the fuel is used.

A feature of the modern autovac is a self-draining float. The central float stem is hollow with a hole drilled in its lower end inside the float and another above the float. Any fuel which gets inside the float is sucked out through the stem during the suction period and air is admitted when the air-valve is open. A small conical filter, easily removed for cleaning purposes, is fitted in the union elbow of the pipe from the main tank to protect the autovac against any foreign matter in the fuel. Any impurities, such as dirt or water, which escape the filter, fall to the concave bottom of the reservoir and can be emptied out through the central drain plug provided in the base of the outer chamber.



When a body rotates, the line about which it turns is known as its axis. An aircraft has three axes of rotation, as shown, and each is perpendicular to the other two, intersecting them at the aircraft's centre of gravity.

AVOGADRO'S NUMBER. The theory put forward by the Italian scientist Avogadro in 1811 that equal volumes of different gases at the same pressures and temperatures must contain the same number of molecules. This supposition was almost ignored until 1858, when it was universally accepted.

It has, however, since been proved definitely by measurement of Brownian movement, by the determination of radiant heat, the counting of α particles, and other methods. The molecule of hydrogen consists of two atoms and the molecular weight is 2; 2 grams of hydrogen occupy 22·412 litres at the normal pressure and temperature, and this volume contains $6{\cdot}06 \times 10^{23}$ molecules. If a gas has a molecular weight of M, then M grams of the gas will occupy the same volume (22·412 litres) and will contain the same number of molecules ($6{\cdot}06 \times 10^{23}$); thus $6{\cdot}06 \times 10^{23}$ is known as Avogadro's number.

AXIS. The line about which a body rotates. The earth's axis is the straight line joining the north and south poles. The axis of a door is the vertical line through the pivot of the hinges, and the axis of a wheel is the line through the middle of the hub at right-angles to the wheel, that is to say, through the centre of the axle.

When considering the motion of an aircraft, it is necessary to define, or fix, three mutually perpendicular axes. These axes are shown in the illustration from which it will be seen that they intersect at the centre of gravity of the aircraft, since all rotation is about this point.

AXLE. The shaft or casing on which the road wheels of a road vehicle are mounted, and which supports the weight of the body and frame through the medium of the springs. On a motor vehicle, the front axle incorporates facilities for steering, and, except in the case of chain-driven vehicles, the rear axle assembly includes mechanism for transmitting the turning effort exerted by the engine, through an angle of 90 deg., to the road wheels.

Both front and rear axles are subjected to forces tending to bend and twist them, caused by acceleration,

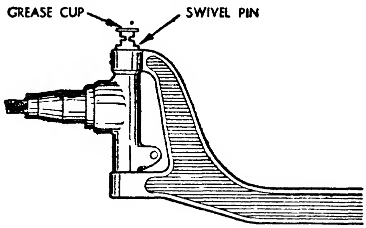


Fig. 1. In what is known as the Elliot front axle, the stub axle swivels between the two jaws on the end of the axle beam. Other types are not fitted with grease cups as shown here.

braking, cornering and road-surface irregularities.

FRONT AXLE. This unit has three principal components: the axle beam, stub axles, and the king pins or swivel pins. The axle beam is a simple steel forging having in most cases, an I or oval section, though tubular or rectangular sections are sometimes used. The beam has two seats on which the springs rest and to which they are secured. To reduce height the beam is bent upward from the seats and terminates at the forked end or eye on which the stub axles pivot. The stub axles are the short swivelling shafts on which the wheels rotate.

Two methods, known as the Elliot axle and the Reverse Elliot axle, are used to hinge the stub axles to the axle beam. In the first method the axle end is forked like a C, the stub axle fitting between the two jaws (Fig. 1): In the second, the stub axle forms the C and the axle end fits between the jaws (Fig. 2). The swivel pin or king

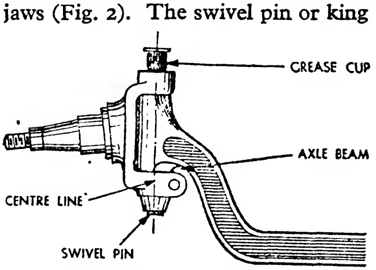


Fig. 2. Another type of front axle is the Reverse Elliot, which has the axle end fitting between jaws on the stub axle, the swivel pin being secured in the forked ends of the main axle.

pin couples the stub axle to the axle beam. On the Elliot axle this pin is fixed in the stub axle and its two ends turn in bushes at the forked ends of the axle beam. In the reverse Elliot axle the pin is secured in the axle beam and the stub axle moves on the pin.

The track rod couples the two stub axles together so that the movement of one is transmitted to the other. Each stub axle carries a track arm to which the track rod is secured by a ball-and-socket joint; in addition one stub axle carries a steering arm to which motion is imparted through the pull-and-push rod and the drop arm from the steering wheel assembly.

REAR AXLE. There are two main types, namely: the solid axle, used mainly in very heavy vehicles where

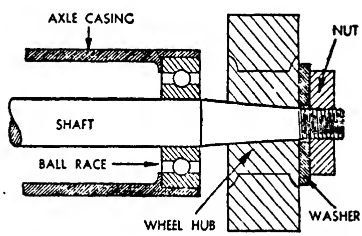


Fig. 3. In addition to transmitting the torque, the shaft in a semi-floating axle, shown here, bears the load.

the drive to the wheels is carried through by means of chains and sprockets; and the live axle, in which a mechanism of gears and shafts is used. The live axle assembly includes the axle casing, reduction gear, the differential, and the axle shafts described below.

HALF SHAFTS OR AXLE SHAFTS. These shafts, which transmit the turning effort from the differential to the hubs of the road wheels are connected to the latter in a variety of ways. Three general methods in use are known, respectively as Fully Floating, Three-Quarter and Semi-Floating Axle.

SEMI-FLOATING AXLE. A semi-floating axle indicates that the shaft transmits torque and also carries the

load (Fig. 3). The shaft is tapered at the wheel end, the hub, secured by a key and nut, fitting over the taper. In most cases the bevel wheel of the differential assembly is integral with the axle shaft.

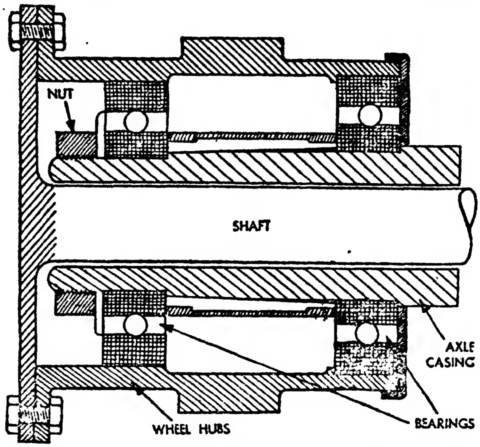


Fig. 4. Vehicles fitted with fully floating axles have the wheels mounted on special bearings, with the result that the shaft merely transmits the torque to the rear road wheels.

Fully Floating Axle. In a fully floating axle the shaft transmits torque only, the wheel being mounted on bearings supported on the axle casing. The full weight of the vehicle is thus transmitted directly from the axle casing to the ground (Fig. 4).

Three-Quarter Floating Axle. This system (Fig. 5) is a combination of two of the previous examples, the load being shared between the axle shaft and the casing. The hub is secured by key and taper but it also carries the outer race of a ball bearing, the inner race of which supports the axle casing.

Axle Bearings. Throughout the rear axle assembly, ball or roller bearings are used. In the lighter type of vehicles they take both radial and thrust loads, but on heavier types separate thrust races are incorporated.

Oil Retainers. These are felt washers, and are used to prevent the oil in the reduction gear and differential assembly from getting on the friction surfaces of the brakes.

Axle Casing. This is the main weight-carrying component; it is made of hollow-steel forgings or pressings, riveted or welded together to form a rigid structure, and encloses the final drive mechanism. Provision is made on the casing for spring anchorage, either integral with the casing or free to pivot on it according to the method used to apply the tractive force to the vehicle. On the ends are the brake-anchorage brackets and, in certain cases, the road-wheel bearings.

It not infrequently happens that the axles of road vehicles are out of alignment. This defect is known as crab-track and is often noticeable by observing the marks made by the tyres on a wet road. It may be checked by laying a long straight-edge against the rim of the rear wheel just below the hub and extending it to the front wheel. Compare the relationship of the front wheel to the rear wheel and to the straight-edge on each side.

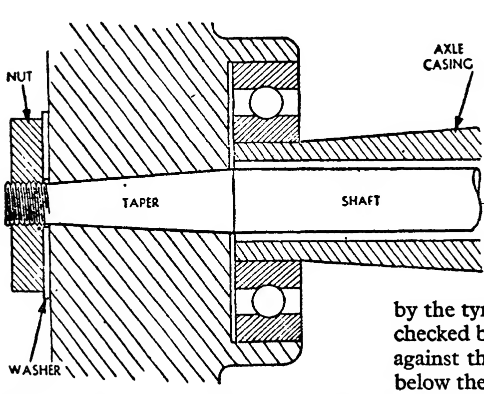


Fig. 5. Shaft and casing each bear part of the load in the present-day three-quarter floating-axle assembly.

BABBITT METAL. Any one of a series of soft white-metal alloys named after Isaac Babbitt who, in 1839, took out a patent for special bearings, in which a soft-metal alloy of copper, tin and antimony was used. Modern Babbitt metals vary in composition according to the pressure they have to withstand, the proportion of lead increasing rapidly the lower the designed loading-per-unit area. For medium pressures an average composition would be: antimony 10·5 per cent; tin 60 per cent; copper 3 per cent; lead 25 per cent; with small quantities of iron and bismuth.

Other factors affecting composition (and therefore mechanical properties) are the speed of rotation and the method of manufacture. Babbitt metal may be either bought as ingots, melted in a ladle and poured into the recesses in the bearings designed to receive it; or it may be cast in position by means of centrifugal action derived from a special machine. The latter process has the advantage of ensuring freedom from blowholes and of making all impurities rise to the surface, from which they are removed during the first cut of the boring machine. The Society of Automotive Engineers (U.S.A.) has published several standard specifications for Babbitt metals for various purposes.

BACK-FIRE. An advanced explosion in an engine cylinder before the piston has arrived at the end of the compression stroke, tending to force the piston down the bore and cause the crankshaft to rotate in the opposite direction to that intended; it should not be confused with an explosion occurring in the silencer due to the ignition there of unburnt gases. Causes of back-fire are (a) incorrect timing of the spark in relation to the position of the piston, (b) wrong assembly of the ignition unit, (c) defective advance and retard mechanism and (d) placing the ignition-control lever in an advanced position when starting. A back-fire is dangerous because, when cranking the engine by hand, the handle may be flung round rapidly in the wrong direction and cause injury or, if the self-starter is used, the occurrence may also damage the drive of the starter.

BACK-INLET GULLEY. A fitment which forms part of a drainage system and may be made of stoneware or cast iron. It comprises a trap and water seal with open grating over, and is arranged so that the incoming liquid from waste and rain-water pipes is discharged above the water-seal level and below the grating, thus preventing splashings and the gradual silting up of the grating. The seal should not be less than 2 in. The outlet pipe is described according to the direction of the bend as a P or S bend.

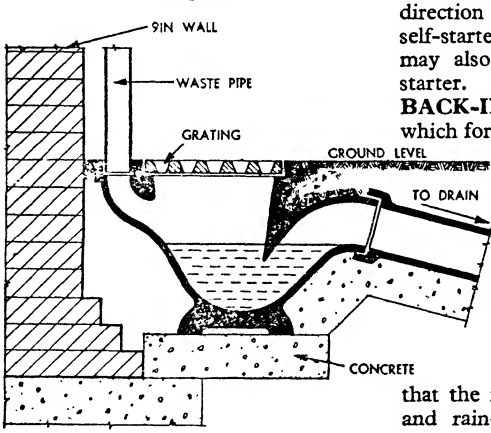


Diagram showing method of connecting a waste pipe to a gulley via a back inlet.

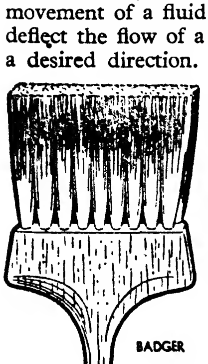
BACKLASH. A term used in engineering to define the free movement between two or more geared units before the effort is transmitted from one to the other, as for example,

when a steering wheel is turned through a large angle before the turning effort is passed on to the road wheels. Backlash in steering assemblies may be caused by wear in the steering box, loose ball joints on the pull and push rod, steering arms, track rods etc. Backlash in the transmission of a road vehicle may be found by jacking-up one of the rear wheels and, with the gear lever in top gear position, turning it lightly backwards and forwards. The amount of free movement indicates the backlash between shaft bevel and differential pinions, crown wheel and pinions (or worm and worm wheels), universal joint and gearbox.

BACK PRESSURE. Opposition to piston movement offered by the burnt gases during the exhaust stroke of an internal-combustion engine. Loss of power is brought about by back pressure because the piston is resisted in the upward motion of the exhaust stroke. This effect, prevalent at high engine-speeds, is greatly increased if the exhaust passages and silencer are choked with carbon deposits.

BADGER SOFTENER. A soft hair brush, as illustrated, used by the painter for fine grain stippling, also for blending and softening one colour into its neighbour, extending the edge of a wet film over a dry surface and generally neutralizing harsh contrasts. Paint is never applied with this type of brush; its function is to manipulate the film after it is applied.

BAFFLE. A plate used to restrict the movement of a fluid or liquid, or to deflect the flow of a liquid or gas in a desired direction.



When in use, a badger softener must be kept as clean and dry as is possible.

A baffle is fitted, for instance, in the fuel tank of a road vehicle to restrict the swirling of the fuel caused by motion of the vehicle. In a two-stroke internal-combustion engine a baffle on the piston crown deflects the incoming explosive charge away from the exhaust port and towards the combustion chamber (see EXHAUST SILENCER).

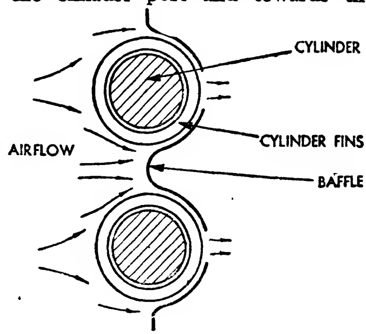
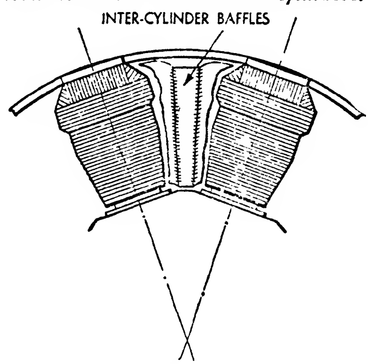


Diagram illustrating (above) plan view of cowling baffles; and (below) front view of baffles between the cylinders.



In aircraft engineering a fairing, or baffle, is placed between the cylinders of an air-cooled engine to ensure that all air passing through the cowling does useful work in cooling the engine. See COOLING.

BAFFLE (Radio). A board on which a loudspeaker is mounted so that the waves radiated from the two sides of the diaphragm (they are radiated 180 deg. out of phase) do not cancel-out each other. If the baffle is round, its diameter should be about half the length of the wave of the lowest note it is desired to reproduce but, ideally, it should be of irregular outline so as to minimize interference at certain

critical frequencies. In most radio receivers, the cabinet itself provides the baffle and reasonable care should be taken to prevent " boominess," or box-resonance, by lining the cabinet with some sound-absorbing material.

In theatres and public-address work, it is quite usual to employ large diaphragm loudspeakers fitted with short horns or *directional* baffles which are, in these cases, useful since they tend to "beam" or direct, the radiation.

BAKELITE. A synthetic resin produced by a reaction between phenol (see BENZENE) and formaldehyde (q.v.). It is an amber-coloured solid which on heating gradually becomes hard and infusible.

BAKING POWDER. Usually a mixture of sodium bicarbonate and tartaric acid, or cream of tartar, with the addition of flour. On being moistened and warmed, baking powders evolve carbon dioxide, which makes dough rise.

BALANCED-ARMATURE LOUDSPEAKER, see LOUDSPEAKER.

BALANCED CONTROL. An aircraft control surface designed to reduce the controlling force which has

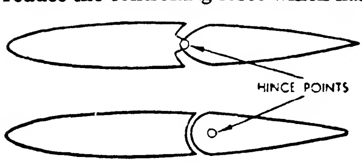
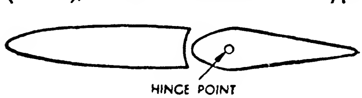


Fig. 1 (above). Diagram showing plain, or unbalanced, control surfaces. **Fig. 2** (below), the nose-balance type.



to be exerted by the pilot. A plain or unbalanced control surface is one which is hinged at its leading edge or at the centre of curvature of its nose radius (see Fig. 1). Control balancing can be achieved in two ways—by placing the hinge aft of the leading edge of the surface, or by a servo tab shown in Fig. 5. Fig. 2 shows the set-back hinge type of control as used

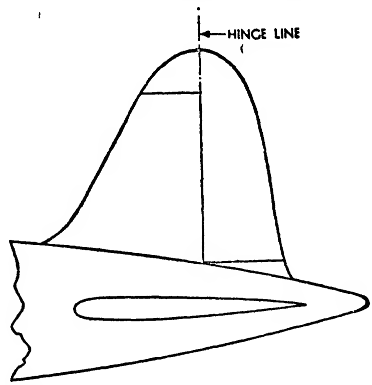


Fig. 3. Horn-balance system as applied to aeroplane rudders and elevators.

for rudder and elevators, where the air forces on the portion ahead of the hinge tend to balance the forces on the portion behind the hinge.

The force movement about the hinge required for a given deflection of the control surface is thus considerably lessened. A special form of nose balance, also used on rudder and elevators, is the horn balance, in which the area forward of the hinge line is concentrated at the tip of the control surface (see Fig. 3). Examples of the types of nose and hinge balance used for ailerons may be seen by referring to Fig. 4. The servo or balance tab consists of a small hinged inset portion of the trailing edge of the control surface, actuated by a linkage which moves it in the opposite direction to that of the control surface, as shown in Fig. 5. The air forces on the tab act in the opposite direction to the

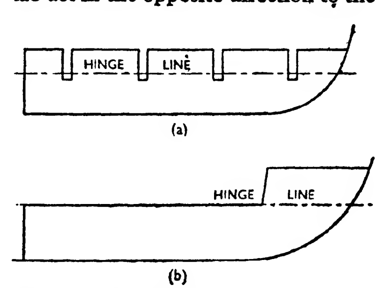


Fig. 4. Balanced aileron control: (a) hinged, and (b) horn balanced.

forces on the control surface, thus reducing the load to be applied by the pilot. The reduction in control effectiveness due to the tab is not very serious. Servo tabs may be used on ailerons, rudder, or elevator.

BALANCER. An electrical machine or transformer which may be used to maintain equality of voltages in a distribution system using more than two wires. See STATIC BALANCER and THREE-WIRE SYSTEM.

BALING (or Faggotting). Loose and bulky scrap from all sheet-metal operations made up into bundles for ease of handling, in a suitable press which delivers bales of any desired size—usually about 2 ft. × 1 ft. 6 in. × 1 ft.

BALL-AND-SOCKET JOINT. A device consisting of a hardened-steel ball fitting between two semi-spherical sockets, used to join two rods together so as to allow one of the rods to move in any direction in relation to the other.

BALLAST RESISTANCE. A resistance used in A.C.-D.C. radio receivers to limit or regulate the heater-current supply to the valves. In such a receiver, the heaters are wired in series and, with the ballast resistance also in series, are connected directly to the mains supply. The required value in ohms is given by:

$$\frac{\text{mains voltage—sum of heater voltages}}{\text{heater current (in amperes)}}.$$

It should be noted that where valve heaters are connected in series they must all be of the same current rating unless, of course, special arrangements are made.

In "midget" receivers, there is often not sufficient space for satisfactory dissipation of the heat produced in the ballast resistance and accordingly the resistance wire, properly insulated electrically and thermally, is made a part of the normal mains-connecting lead.

This *line cord*, as it is called, should, therefore, not be coiled up or placed, for example, under a carpet, since the heat produced in it must be able to escape freely to the air. Also, since its resistance is determined by its length, it must not be shortened.

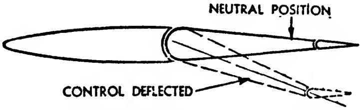


Fig. 5. Control surface with servo-tab.

BALL BEARING, see BEARING.

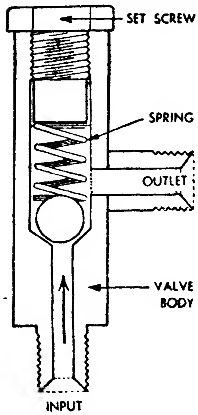
BALLISTIC GALVANOMETER. A galvanometer (q.v.) suitable for measuring small quantities of electricity as in the discharge of a condenser. It is designed with a heavy movement so that the discharge is complete before the galvanometer moves appreciably.

BALLISTICS. The science of gunnery. It is concerned with the path (*trajectory*) of a *projectile* (bullet, shell, etc.), driven by a *propellant* (usually hot gases produced by an explosive charge). The velocity of a projectile, projected with velocity v at an angle α to the horizontal, may be resolved into two components: v cos α horizontally, and v sin α vertically upwards. The former is constant throughout the motion except as it is affected by air resistance. The latter decreases to zero, owing to the weight of the projectile, then increases downwards. The path of a projectile is a parabola. Suppose a shell is fired at an elevation of 30 deg. with a muzzle velocity of 2,000 feet per second. The vertical velocity is 2,000 sin 30 deg $= 2{,}000 \times \frac{1}{2} = 1{,}000$ feet per second. At the highest point on the trajectory the vertical velocity is zero, and $v = gt$, where g is the acceleration due to gravity, and t is the time in seconds to attain the highest point: $t = \frac{v}{g} = \frac{1000}{32} = 31\frac{1}{4}$ seconds. The total time of flight is $31\frac{1}{4} \times 2 = 62\frac{1}{2}$ seconds. The horizontal velocity is 2,000 cos 30 deg. $= 2{,}000 \times \frac{\sqrt{3}}{2} = 1{,}732$ feet per second.

Hence the range is $1{,}732 \times 62\frac{1}{2}$ feet $=$ 20·5 miles.

BALL RACE, see BEARING.

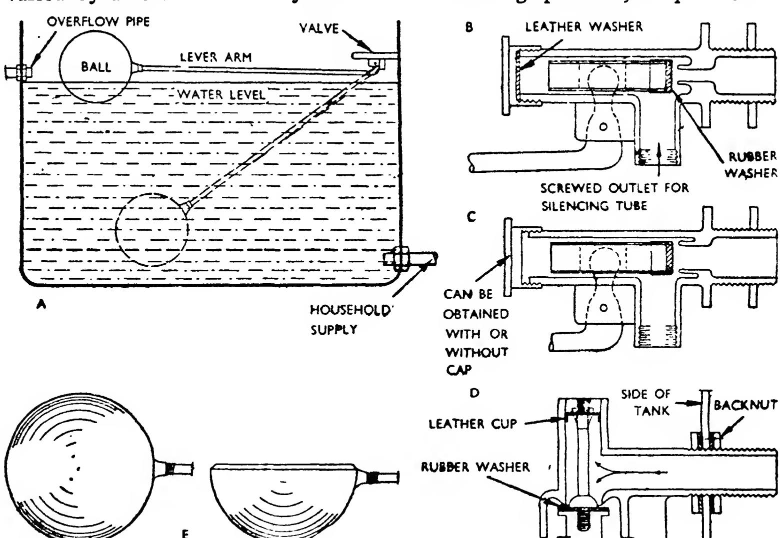
BALL VALVE (Mech. Engineering). A valve frequently employed in engine



Non-return valve frequently used in lubrication systems and in hydraulic and air circuits.

lubrication systems and in hydraulic or air circuits where non-return of the fluid or air after it has passed a certain point is essential. The body of the valve is a counter-bored tube screwed on the inside of the larger diameter. The ball rests at the junction of the two diameters, held in position by a spring, as shown in the accompanying diagram, the tension of which can be varied by a screw secured by a lock nut. Above the ball is an outlet hole; a pressure of oil through the input hole of the valve, forces the ball off its seat against the spring and allows a free passage of oil through the outlet hole. If the pressure is reversed, the ball is forced more tightly on to its seat, thus preventing the flow of oil in the opposite direction.

BALL VALVE (Plumbing). A device which controls automatically the entry of water into a storage or flushing cistern. Various types have been evolved, for high-pressure, low-pressure and automatic flushing cisterns, but the general principle is shown in the illustration. A hollow float attached to the end of a lever arm rises as the level of water rises in the cistern and forces a rubber washer against the orifice through which the water enters. Where high pressure has to be contended with, this orifice is smaller than in the low pressure type. For extra high pressure, an equilibrium



BALL-VALVE ASSEMBLY FOR COLD-WATER CISTERNS

Various methods of controlling the flow of water to a cold-water cistern are in general use but the principles are the same. At *A* is shown a typical cistern assembly with ball valve. There is a number of types of valve; the Portsmouth high-pressure valve is shown at *B*, while that used for low-pressure systems (shown at *C*) has a wider inlet orifice. An equilibrium ball valve is shown at *D*, and at *E* are given two types of float widely used, one ball-shaped, the other flat-topped.

type can be obtained which allows the water pressure to act on both sides of a piston, thereby neutralizing its force, or tendency to push the valve open. The reverse-action ball valve is for use in automatic flushing cisterns to prevent repeated siphonic action. A slow flow is permitted immediately the cistern has flushed, with a gradually increased flow as the cistern fills.

High-pressure valves should be used on main water supplies, and on downservices where there is a considerable head of water. Low-pressure valves should be used where the head is less than 15 ft. and full-way valves where the head is less than 6 ft. Equilibrium valves should be used in cases of extreme high pressure, or where water hammer cannot otherwise be cured.

Floats can be made of glass or plastic materials, but are usually of copper with a soldered seam. Where the latter are used in a soft water district, and are therefore subject to electrolytic action, they should be painted or coated, or Sifbronze welded.

BALTIC WHITEWOOD, see FIR.

BAND-PASS TUNING. A radio tuning system employing coupled circuits so as to respond to a band of frequencies and, thereby, to preserve good quality speech or music. A radio transmission, although generally stated to be of a particular frequency actually occupies a band of frequencies in the radio spectrum. For example, if a carrier frequency be, say, 1,000 kilocycles (Kc/s.), and if the modulation or intelligence be represented by a pure tone of 5 Kc/s., then the frequencies actually radiated by a transmitter are (a) 1,000 Kc/s., known as a fundamental (b) 995 Kc/s., and 1,005 Kc/s., the latter being known as lower and upper side-bands respectively.

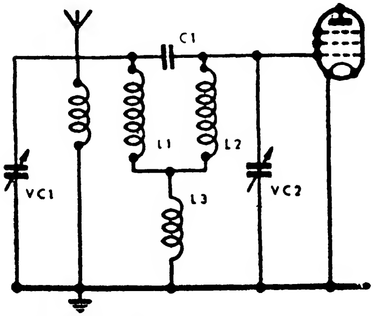


Fig. 1. Typical band-pass circuit as described in the accompanying text.

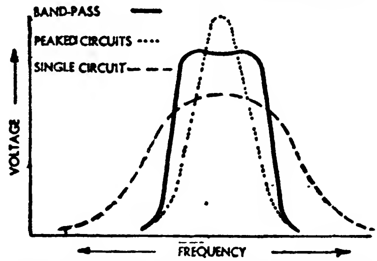
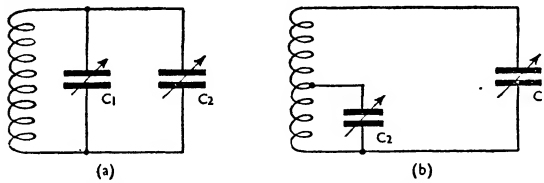


Fig. 2. Diagram showing performance of a band-pass arrangement compared with the response of simple circuits.

Since any intelligible speech or average-quality music will cover all frequencies from a few cycles per second up to at least 5 Kc/s., it is clear that a broadcast transmitter will radiate complex side-bands and that the ether space required will be represented by a band some 10 Kc/s. broad. A simple single circuit is unable to cope satisfactorily with such a wide band and would severely attenuate the remoter side-bands (that is, those most remote from the fundamental or carrier frequency) resulting in deficient reproduction of the higher notes which are conveyed by those side-bands. To overcome this difficulty, the band-pass circuit is employed. Basically, such an arrangement deals with fundamental and side-band frequencies but excludes unwanted signals on adjacent wavelengths. A typical circuit arrangement is shown in Fig. 1 where L1, VC1 and L2, VC2 are two identical tuned circuits coupled together by C1, L3 which represent the common impedance. Such coupling is usually termed "mixed coupling". Its effect as compared with those of single and peaked circuits is shown at Fig. 2.

BANDSPREADING. A tuning refinement employed in many of the better types of short-wave radio



Two methods of bandspreading. In each case the bandspread condenser, C_2, tunes through a narrow band of frequencies; the approximate frequency of the band is set by the adjustment of the variable condenser C_1.

receiver. For ease of tuning, it is convenient to arrange that a whole dial scale is occupied by what would normally be a comparatively narrow band.

Two of the many methods used to achieve this are shown in the illustration. In method (a) a small capacitance bandspread condenser C_2 is used in parallel with the larger main tuning condenser C_1. The arrangement shown at (b) uses a small bandspread condenser C_2 connected across only a part of the coil. C_1 is the normal main tuning or band-setting control.

In both the systems illustrated, C_2 is adjusted quite separately from C_1 and is provided with a calibrated, or marked, scale distinct from the main dial. Mechanical and electrical systems in which the full variation of the normal knob covers only a narrow frequency band can be devised.

BARIUM (Ba). Atomic no. 56; atomic wt. 137·7; a soft silver-white metal prepared from barytes, $BaSO_4$, witherite, $BaCO_3$, and other minerals. It is bivalent and forms an oxide BaO and a peroxide BaO_2. The element is a mixture of seven isotopes, the principal ones having atomic weights of 136, 137, and 138.

BARIUM SULPHATE, $BaSO_4$, is largely used as a pigment under the name of blanc fixe (q.v.), and it forms a component of the pigment lithopone, which is an intimate mixture of about 70 per cent of barium sulphate and about 30 per cent of zinc sulphide.

BARIUM SULPHIDE, BaS, is a white powder that is usually very phosphorescent, and is used for that reason.

BARKHAUSEN OSCILLATIONS. Oscillations of extremely high frequency generated by a triode valve; its grid being at a moderately high positive potential and its anode at zero or a slightly negative potential. In these circumstances, most of the electrons attracted by the grid pass between the wires of the grid after which, due to the relatively negative anode, they lose velocity and tend to return to the grid but, in fact, oscillate about it at a frequency determined by the physical dimensions and disposition of the electrodes and the voltages applied to them. These oscillations are sometimes called *electron* oscillations.

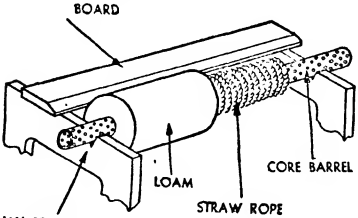
BAROGRAPH. An instrument for recording, automatically, the readings of a barometer. A pencil is attached to the end of a pointer which moves up and down with the increase or decrease of air pressure. The pressure is recorded on a revolving drum by the pencil.

BAROGRAPH (Aero. Engineering). A recording altimeter. A chart wound on a drum is rotated slowly by a clockwork motor while a small pen, connected to a mechanism similar to that of a normal altimeter is kept in contact with the chart and traces out a graph of altitude against time. A sealed barograph is carried to verify the height reached during attempts to establish new altitude records.

BAROMETER. An instrument for measuring the pressure of the atmosphere. The barometer in use in scientific work is the mercury barometer: a glass tube about 36 in. long, closed at one end, is filled with mercury and inverted so that the open end dips into an open vessel containing mercury. The level of the mercury in the tube falls until it is about 30 in. or 76 cm. above the surface of the mercury in the open vessel, leaving a vacuum at the top of the tube. The weight of the mercury in the tube balances the pressure of the atmos-

phere on the mercury in the open vessel, and the height of the mercury in the tube is a measure of the pressure. For very accurate work corrections must be made for the temperature, for the height above sea-level, and for the latitude of the locality. An aneroid barometer is marked by comparison with the mercury barometer. See ANEROID BAROMETER.

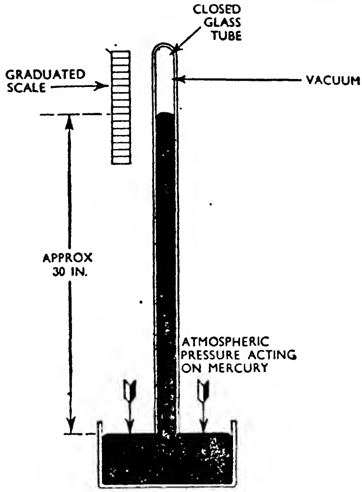
BARREL CORES (Foundry). Loam cores formed on an iron or steel barrel. The barrel should be 2 in. to 3 in. smaller in diameter than the required core. It is set up in 'V' bearings on a pair of trestles, and straw rope wound round tightly. Weak clay is rubbed over the surface, any excess being cleaned-off by pressing a piece of wood firmly against the straw while the barrel is being rotated. This operation should leave a fairly solid foundation on which to shape the loam. A striking board is set-up leaving about ¾ in. between its edge and the straw. Loam is fed as required, and is shaped by the striking board as the barrel is rotated. It is advisable to



Set-up for making a barrel core. Note "V" bearings for locating barrel.

check the diameter of the core at this stage, and to correct the position of the striking board if necessary. If a suitable barrel is not available, a smaller size may be used, adding extra layers of straw rope. Care is necessary, however, or the core will become loose on the barrel during the drying process.

BARREL PLATING. A process for depositing metals electrolytically (see ELECTRO-DEPOSITION) on to small metal parts for purposes of decoration or protection. The barrels used



In the mercury barometer, the weight of the mercury in the tube is balanced by the pressure of the atmosphere.

are of various types. In one type the barrel is made of wood or ebonite, closed at the bottom and open at the mouth, and is rotated slowly about its axis while inclined at an angle of about 45 deg. Contact with the parts being plated is made by means of a series of metal studs or strips set in the bottom and connected with the negative pole of a suitable source of direct current. The anode may be suspended from above, dipping into the plating solution contained in the barrel, or it may be in the form of an internal anode entering the barrel through the bottom. The barrel itself can be tilted to any desired angle by a gearing arrangement and inverted for unloading purposes.

Other types of plating barrel make use of perforated containers of an insulating material rotating horizontally in a tank of plating solution; in this type of plant heated solutions can be used. Relatively thin deposits only can be applied by barrel plating in a reasonable time, because the tumbling action of the barrel tends to remove some of the metal deposited, and also because of the intermittent nature of the contact of the parts with the

cathode. A higher voltage is required than with ordinary plating in tanks, while the solutions used should be of high electrical conductivity.

BARRETTER. A current regulator. A device designed to maintain substantially constant, within certain limits, the current passing through it, in spite of fluctuating values of voltage across it. It consists, generally, of a fine resistance wire in a hydrogen-filled bulb. If the applied voltage is raised, increase of current causes the temperature of the wire to rise, and this results in an increase of resistance, thereby reducing the current. Conversely, if the applied voltage is reduced, the temperature of the wire drops, the wire is lowered in resistance and tends to restore the current to its normal value. It may be employed to compensate for variations of mains-supply voltage and also to obviate the necessity of tapped resistances in A.C.-D.C. receivers. A barretter is, in fact, commonly used in such receivers in the position of the ballast resistance (q.v.). It regulates the current to the value necessary for the series-connected valve heaters and renders it unnecessary to make any adjustment when connecting the receiver to any mains voltage between say, 200 and 250.

BARYTES. A dry, soft powder form of the natural heavy spar-like mineral, barium sulphate, used as an extender in the making of paints. When produced by precipitation this barium compound is known as blanc fixe (q.v.).

BASIC LEAD CHROMATE, see CHROMIUM.

BASIC STEEL. Steel made by refining high-phosphorus pig iron under a strongly basic slag in a furnace having a basic bottom and lining. Basic steel may be made in Bessemer or open hearth converters, or in the electric furnace. The function of the basic lining and slag is to remove phosphorus from the melt.

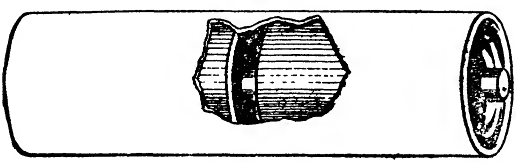
The phosphorus is oxidized to form an acidic oxide which reacts with the basic materials in the furnace and so passes into the slag. The reaction proceeds only if oxidizing conditions are maintained and the slag contains an excess of lime. Manganese, carbon and silicon are also removed, but the content of the silicon in the charge should be low or removal of phosphorus will be slow and there will be a considerable wastage of lime. When the impurities have been removed to a sufficient extent, the slag must be removed or the phosphorus will be returned to the melt when deoxidation is attempted.

For this reason, therefore, the additions of ferro-manganese, ferro-silicon etc., necessary to deoxidize the melt and to introduce the correct proportions of carbon and manganese, are often made in the ladle. Deoxidation causes a cloud of slag particles to form in the molten steel. These rise to the surface and so escape. As the time available for separation is short, complete removal of the slag is not always obtained. For this reason, basic steel tends to contain more non-metallic inclusions than steel made by other processes.

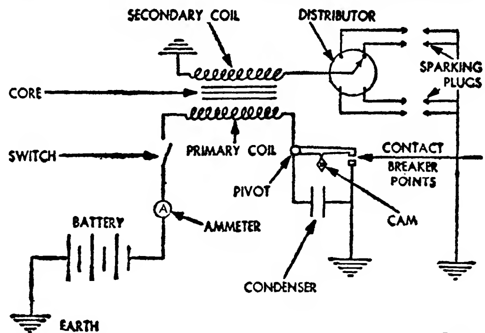
BASSWOOD, see CANARY WOOD.

BATTENBOARD, see LAMINATED BOARD.

BATTERY. An assembly of several items of equipment grouped together. In the electrical sense, the term denotes two or more primary or secondary cells electrically connected, usually, but not necessarily, in series. A primary battery is shown in the diagram, while the accumulator employed in motor cars provides an example of a secondary battery. See PRIMARY CELL and SECONDARY CELL.



Dry battery used in the electric torch. A section of the outer covering is cut away to show the two cells. The case of each cell is the negative and the brass cap, the positive.



Circuit diagram for battery-and-coil ignition. A typical earth-return system such as this which has a six-volt battery, has an induction coil which transforms the low-tension voltage, known as the primary current, into a high-tension secondary current. A distributor unit delivers the high-tension current to the sparking-plugs in the firing order appropriate to the particular engine. A cam-operated contact-breaker and a switch are provided.

BATTERY-AND-COIL IGNITION. An ignition system for motor vehicles in which the current is supplied by an accumulator, usually spoken of as the battery; an *induction coil* steps-up the low-tension battery's voltage into a high-tension voltage to create the spark. In order to interrupt at regular intervals the flow of current through the primary winding of the coil unit, a contact-breaker is used. A distributor delivers the high-tension impulse to the cylinders in their correct firing sequence. The contact-breaker and distributor are contained in one unit known as the distributor, which is positively driven from the engine at half-crankshaft speed.

In addition to these functions, the distributor unit contains a centrifugally operated device for advancing, according to engine speed, the timing of the spark in relation to the piston position. The contact-breaker consists of two metal points, one fixed and the other movable, supported on an insulated base, one of the points being earthed. The moving point is attached to a pivoted rocker arm, which is acted upon by a cam to separate the points. The cam, which has as many lobes as there are cylinders, is rotated by the distributor spindle. The advance mechanism causes the cam to be moved in the direction of rotation as engine speed increases. In order to minimize sparking at the contact-breaker points when they open, which would delay the "break," a condenser, its two terminals connected to the two points, is used (see CONDENSER). An insulated arm with a metal terminal strip, known as a rotor arm, is supported on the top of the moving cam and is keyed to it to ensure a positive drive. This arm rotates within a *cylindrical* cover, made of insulating material, which fits over the contact-breaker assembly and is held in position by two spring clips. The cover carries a number of equally spaced metal segments projecting around its inner circumference. There are as many segments as cylinders and the rotor arm sweeps past these segments in turn as it rotates. There is a small clearance between rotor and segment, across which the H.T. current jumps, so that they do not make metallic contact.

A distributor cover for a four-cylinder engine would have four segments, each in contact with a terminal on its outer surface connected to the plugs, and through a small carbon brush a fifth terminal at its centre would contact the rotor arm supplying the H.T. current from the coil. A typical "earth-return" ignition system is shown in the illustration.

BATTERY ELIMINATOR. A device for obtaining current supplies for a radio receiver from the electric-supply mains, popular some years ago when the majority of listeners had battery-operated sets. Now that mains receivers are little dearer than battery models, the need for the eliminator has disappeared. Eliminators were obtainable to work from either D.C. or A.C. mains and the latter type often provided, as well as

H.T. current, trickle charging arrangements for the L.T. accumulator. The unit comprised smoothing components, voltage-dropping resistances and, in the case of A.C. models, a rectifier, usually of the metal type.

BEARING. That part of a piece of mechanism which supports a rotating shaft or rotating wheel on a fixed shaft. Bearings are of three types—plain, ball, and roller. The first type can be subdivided into sleeve and split bearings, also into certain special forms, such as footstep bearings for supporting vertical rotating shafts.

In bearings of this type, however, use is made of one or other of the long series of special bearing alloys often designated as "bronze". The exact composition for the best results under given conditions will depend upon the hardness of the shaft steel, the speed of rotation, type of lubrication, loading, and other factors. In plain bearings, the aim should be to use the lowest-viscosity oil, together with the highest bearing pressure permissible for safe running. The running temperature in general practice is not allowed to exceed 140 deg. to 160 deg. F. Another important factor is the *clearance*, i.e., the difference between the external diameter of the shaft and the inside diameter of the bearing; the *ratio* of the clearance to the shaft diameter is a further matter of importance. In accurate work the clearance may be as low as one-thousandth of the shaft diameter; in

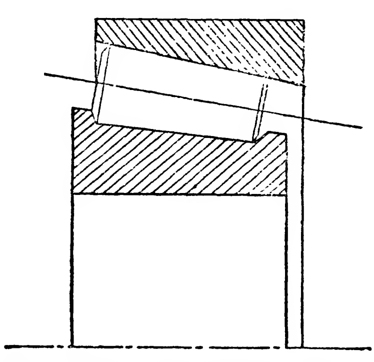


Fig. 1. Roller bearing widely used for carrying radial and thrust loadings.

less accurate components it may reach three or four thousandths. The ratio of length to diameter is kept as low as possible, in modern designs, so as to prevent unnecessary absorption of power by friction.

BALL BEARINGS are of two chief kinds: thrust bearings and radial bearings, the former being designed for axial loading and the latter for loads at right-angles to the shaft. Radial bearings will, however, withstand a certain amount of axial thrust in addition to normal loading; if the loads are considerable, roller bearings, of the special form evolved for the purpose, should be used (see Fig. 1).

Ball and roller bearings may be classified, for selling purposes, according to the limits of accuracy to which the components are finished; they are known as "alloy", A, B and C grades. The alloy-grade balls are finished to 0·0001 in.; grade A balls do not vary more than 0·0001 in.; grade B, 0·0002 in., while grade C are usually balls rejected from higher grades, as a result of surface defects.

In road vehicles where only radial loads are carried, a plain bearing or bush takes the form of a cylinder pressed tightly into its housing to prevent subsequent movement, the shaft which it supports being free to rotate. When both radial and thrust loads are carried, flanged ends are provided and the journal, which is that part of the shaft lying within the bearing, is shouldered. When both ends of the journal are shouldered, the bearing is halved to allow for assembly; it can then be fitted around the journal, or the shaft laid in position in one half of the bearing and the remaining half or cap bolted on. In order to maintain strength and reduce friction, plain bearings of this type are usually lined with white metal.

Ball bearings are used for their low frictional properties.

BALL RACE. This is made up of two hardened steel rings of rectangular section and different diameters. The inner surface of the larger ring and the outer surface of the smaller each has

a groove or track in which steel balls roll. To assemble, the small ring is placed within the larger and the intermediate space filled with steel balls which are equally spaced by a cage, in which they are free to move. This kind of race is termed a radial bearing, but it can withstand thrust loads up to a point (see Fig. 2).

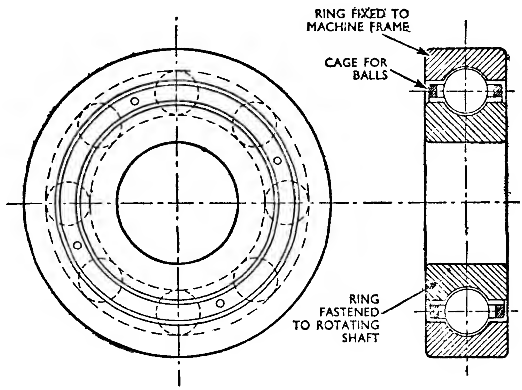


Fig. 2. Diagram showing construction of a ball bearing for a journal, as widely used in various types of engine and machine. Note the cage for holding the balls.

ROLLER BEARINGS. These, which are similar to ball bearings, save that rollers take the place of balls, are of three main types; parallel, taper and needle.

Parallel Roller Bearings. The tracks are not grooved, and small cylindrical rollers replace the steel balls. They can carry greater radial loads than ball bearings of a similar size, but will not withstand thrust loads.

Taper Roller Bearings. These have conical tracks and the rollers are tapered as shown in Fig. 1. This allows thrust loads to be taken in one direction. As in ball bearings, the rollers are spaced by a cage which prevents their touching each other.

Needle Roller Bearings. These are a variation of the parallel roller, but the rollers are much longer and thinner, and completely fill the space between the inner and outer rings; a cage is unnecessary.

THRUST BEARINGS. Thrust bearings are designed to take thrust loads only, and are made of two hardened steel disks, with a hole in the centre, grooved on the flat surface to form a track for the steel balls. The balls may be carried in a cage, but this is often omitted.

The inner race or ring of any ball-bearing assembly should be a good fit on the shaft, and the outer race a push-fit in its housing but tight enough to prevent subsequent creeping. Cleanliness and correct lubrication are important, for small particles of dirt and metal soon destroy a race.

BEAT FREQUENCY. A frequency which is the difference between two other frequencies. For the reception of continuous-wave signals, it is necessary to provide a local oscillator whose frequency differs from the signal frequency by an amount corresponding to an audio frequency. After demodulation, the difference frequency or beat note is heard in the headphones. This is known as the heterodyne method of reception.

In the superheterodyne receiver, a similar principle is involved. The beat frequency is, in this case, supersonic and is spoken of as the intermediate frequency. See FREQUENCY CHANGER and SUPERHETERODYNE RECEIVER.

BEAUFORT SCALE. A scale of wind speeds devised by Admiral Beaufort in 1805. It enumerates twelve speeds: 1 to 3 m.p.h., light air; 4 to 7 m.p.h., light breeze; 8 to 12 m.p.h., gentle breeze; 13 to 18 m.p.h., moderate breeze; 19 to 24 m.p.h., fresh breeze; 25 to 31 m.p.h., strong breeze; 32 to 38 m.p.h. moderate gale; 39 to 46 m.p.h., fresh gale; 47 to 54 m.p.h., strong gale; 55 to 63 m.p.h., whole gale;

64 to 75 m.p.h., storm; above 75 m.p.h., hurricane.

BED (Foundry). Part of the foundry floor reserved for the making of core irons. Generally, a cast-iron frame about 6 in. deep is set to spirit level in the floor with about 2 in. of the frame *projecting* above floor level. The bed is first dug out to a depth of 18 in. and then filled with riddled sand in layers about 6 in. thick, each layer being trodden down lightly but evenly. The last or top layer is scraped smooth by means of a straightedge, leaving the sand about ¼ in. above the edge of the frame. The bed is finally made firm by tapping the ends of the straightedge on the frame, and is then ready for use. See CORE IRONS.

BED AREA. The limiting dimensions of that part of a press body to which the pressure plate is attached; it forms the space available for the support of the work, and can be covered by the tools operating from the ram.

BEDDING-IN (Foundry). Making the bottom half of a mould by pushing the pattern into the sand instead of ramming sand round the pattern. In this way the mould can be made right way up and the need for turning over is avoided. This is often convenient, especially for large work, if the cranes available are insufficient in power or number to permit the more usual method. Patterns are usually bedded in holes dug in the foundry floor or, if very large, in reinforced pits. A hole, roughly the shape of the pattern, but a little larger, is first dug and flat-rammed. Facing-sand is then added and the pattern bedded-in by tapping until it is approximately at floor level. The tapping necessary is a matter of experience, flat, shallow patterns requiring less than deep ones. The cope or any intermediate parts of the mould are then made in the usual way.

BED MOULDING (Building). A collection of mouldings situated immediately beneath the corona of a classical cornice.

BEECH. A hard and heavy wood, light-brown in colour, with fine, even texture and a close grain, found mainly in Europe and Australia; not durable for exterior work. The Australian varieties are more favoured for joinery, the European type having few uses, except for tools and where resistance to wear is important. See TIMBER.

BEKK SMOOTHNESS TESTER. An instrument for measuring the surface smoothness of paper. The rate at which air flows across the surface of the paper when under pressure against an optically flat polished glass ring is taken as a measure of the smoothness of the sheet of paper under test. The glass ring is mounted in a metal seating, and the centre hole connected to a vacuum chamber which is acted upon by a hand pump. The paper under test is placed over the glass ring; between this and the down-bearing pressure-plate is a soft rubber sheet. A partial vacuum of 0·5 atmosphere is produced in the chamber between the paper and the glass, and the time taken in seconds for 10 cc. of air to pass across the paper-glass seal to this vacuum chamber, recorded on a mercury manometer, is the measure of the smoothness of the paper. Leakage over a rough surface will be greater in a given time than leakage over a smooth surface and, therefore, the smoother the paper the higher the reading.

BEL, see DECIBEL.

BELT. An endless strip of pliable material, generally leather or balata, used for the transmission of rotary motion, through frictional contact alone, from one pulley to another. If the belt length is horizontal, it is an advantage to have the slack side at the top ; this arrangement makes for a greater arc of contact, as the upper side of the belt tends to sag. For a given ratio of diameters, large pulleys will transmit more power than small pulleys ; moreover, for a given measure of cross-sectional area, narrow belts are proportionately more effective than wide belts. For good working results the diameter of the larger pulley should not exceed six times that of the small pulley.

Although belt speeds up to 6,000 ft. per min. are practicable on ordinary

drives the optimum speed is about 4,000 ft. per min. Speeds greater than 6,000 ft. per min. require special pulleys and great accuracy in tuning up. The coefficient of friction for ordinary leather belting on cast-iron pulleys is about 0·4 but this will be less if the belts are frequently shifted, as, for instance, in the driving gear of a planing machine.

What is known as the ultimate strength, or breaking stress, of leather belts may be as high as 9,000 lb. per sq. in., but it is usually between 5,000 and 7,000 lb. per sq. in. Working stresses are, as a rule, expressed in pounds per inch-width of belt and, in single belts, vary from 70 to 100 lb.

Assuming, for practical purposes, that no slip takes place between a flat belt and the pulley round which it travels, the horse-power (P) which can be transmitted by the belt may be approximately calculated from the following formula :—

$$P = \frac{(T_1 - T_2)V}{33{,}000}$$

where T_1 denotes the tension on the tight side of the belt, T_2 the tension on the slack side of the belt (both expressed in pounds), and V the velocity of the belt in feet per minute. The effective tension $(T_1 - T_2)$ will depend in practice upon the arc of contact on the pulleys, the belt weight and thickness, and the nature and quality of the belting material. High belt speeds make for high efficiency, but in many installations the belts are run at only one-half or even one-quarter of their optimum speed.

For the transmission of power by belts, speeds of 4,000 to 4,500 ft. per min. have been found economical, and their more general adoption would enable existing belt widths to be much reduced in many cases, with resulting economies. Moreover, bearing pressures would be reduced as a consequence of using a lighter belt; hence lubrication economies would also be achieved. Different considerations apply to V-belt drives.

In recent years woven or balata belting has largely replaced the leather variety. Woven beltings are strong and pliable and are unaffected by changes in temperature or by the presence of chemical fumes, steam, or water. Steel belts are also used for light high-speed work. Their widths vary from 1 to 8 in., and their thickness from 0·2 to 1 mm. Pulleys used with steel belting require a cork facing, which is usually glued direct on to the pulleys or on to a piece of canvas cemented on to them.

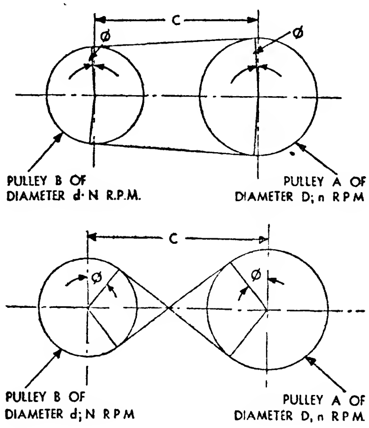


Diagram showing method of calculating length of belt needed to connect two pulleys, by open and crossed drive.

Length of Belts. Consider two pulleys, A and B, of respective diameters D and d, connected by a belt. Pulley A revolves at n r.p.m. and pulley B at N r.p.m. Assuming that no slip occurs between belt and pulley, the following relations hold :—

$$V = 3{\cdot}14\, n\, D = 3{\cdot}14\, N\, d$$

where V is the actual belt speed in feet per minute. Taking the thickness of the belt into account, the *effective* diameter of each pulley is that of the pulley itself plus the thickness of the belt; the effective diameter should be used whenever possible in actual calculations.

To find the length of belt needed to connect two pulleys, it must first be known whether the belt is to be open or crossed as shown above. Then either draw the belt and pulleys

accurately to scale, or use the following calculations. The centre distance between the pulleys is C.

For open belt:—First find the sine of the angle ϕ from the formula $\sin\phi = \frac{D-d}{2c}$. Knowing $\sin\phi$, find the angle ϕ in degrees from trigonometrical tables; then convert the degrees into radians. (1 radian = 57·3 deg.). Then if L denotes the total length of the belt, $L = \frac{\pi}{2}(D+d) + \phi(D-d) + 2c\cos\phi$. Here ϕ must be expressed in radians.

For crossed belt:—First find the angle ϕ in degrees from the formula $\sin\phi = \frac{D+d}{2c}$. Convert ϕ into radians by dividing by 57·3.

Then $L = (\frac{\pi}{2}+\phi)(D+d)+2c\cos\phi$.

Here again ϕ must be given in radians.

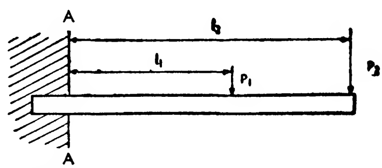
BENCH TEST. A means of verifying adjustments and performance before an internal-combustion engine or component is fitted. When assembled, the engine is bolted to a stand and is run under its own power, but for a given time at a slow speed. This running-in removes slight surface inequalities of bearings, pistons, cylinders etc., and brings to the notice of the tester any defects that may develop as a result of faulty workmanship or materials. When the running-in is completed, the flywheel is coupled to a device for measuring the power output of the engine over a varying range of speeds: the measurement is then compared with known data and, if the comparison is unfavourable, adjustments are carried out until the unit is considered correct.

One means of measuring this power output, which has been widely used, is by use of a dynamo rotated by the engine on test. The output of the dynamo is measured by both an ammeter and a voltmeter, the product of the two readings giving, in watts, the power developed; as one horse-power equals 746 watts the developed horse-power can be easily calculated. The energy developed by the dynamo is passed through a suitable resistance.

Another apparatus, known as a water brake, consists of a water-tight metal casing mounted on bearings and filled with water. Around the inside of the casing are a number of fins, while an engine-driven shaft passing through the centre has attached to it a number of vanes rotating, with a small clearance, within the fins of the casing. The vanes rotate in water and tend to drag round the whole casing, but this movement is resisted by a weight arm attached to the casing. The brake horse-power is calculated from the length of the weight arm, the weight required and the revolutions per minute of the shaft.

BENDING, see POWER PRESS AND PUNCHING MACHINE.

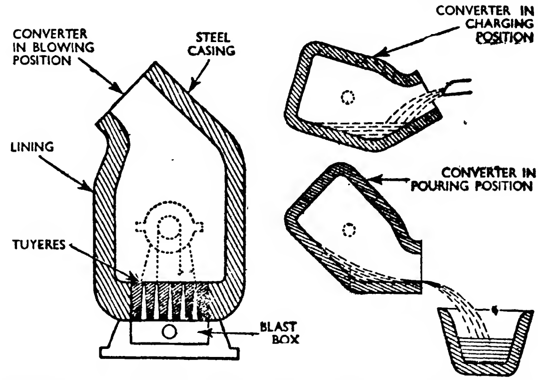
BENDING MOMENT. A measure of the bending effect of forces acting on a beam. Consider a beam rigidly



Bending moment at AA on a rigidly supported beam is calculated by the formula given in text, when l_1 and l_2 are respective distances from AA at which forces P_1 and P_2 are applied.

supported at one end and acted on by two forces P_1 and P_2 as shown in the diagram. The bending moment at AA is given by $P_1 \times l_1 + P_2 \times l_2$.

BENZENE (C_6H_6). A compound of carbon and hydrogen consisting of six CH groups placed symmetrically in a flat regular hexagon. Benzene is a colourless, inflammable liquid boiling at 80·2 deg. C. It is obtained on a large scale in the distillation of coal-tar, and is also recovered from town gas by activated carbon or other methods. It has a pleasant, characteristic smell, and is a starting point in the manufacture of thousands of useful compounds, known generally as aromatic compounds whether they have a



Bessemer converter of the type used in making steel by the process of blowing air through molten pig-iron.

smell or not. The hydrogen atoms are easily replaced by other atoms or groups; sometimes one atom is replaced, sometimes two or more.

The following are among the most important of the derivatives of benzene.

Phenol, C_6H_5OH, is a solid that is readily soluble in water, and the solution is often called carbolic acid. It is largely used as a disinfectant and an antiseptic, and is used in considerable quantities in the manufacture of dyestuffs.

Aniline, $C_6H_5NH_2$, is a colourless, oily liquid, insoluble in water, but soluble in alcohol, benzene and other liquids. It is a starting point in the manufacture of innumerable dyestuffs.

Nitrobenzene, $C_6H_5NO_2$, is a colourless liquid with a characteristic smell, and is prepared by treating benzene with a mixture of sulphuric and nitric acids. When it is treated with iron and a little hydrochloric acid it is reduced to aniline.

Toluene, $C_6H_5CH_3$, is a colourless liquid obtained in the distillation of coal-tar. It is important in the manufacture of dyestuffs.

Trinitrotoluene, $C_6H_5(NO_2)_3$, is prepared by treating toluene with sulphuric and nitric acids. It is a yellow crystalline solid, known as T.N.T., and is a powerful explosive.

BENZINE. A mixture of hydrocarbons consisting of the fraction of crude petroleum boiling between 70 and 90 deg. C.; also known as benzoline, or gasoline. It is a solvent for fats, oils and many vegetable products, and is used as a motor fuel and for cleaning textile materials.

BERLIN BLUE, see PRUSSIAN BLUE.

BERNOULLI'S EQUATION. Bernoulli's equation states that in a stream of fluid of constant density p in which the velocity is changing, the pressure P and velocity V at any point are connected by the law

$$P+\tfrac{1}{2}pV^2=\text{a constant.}$$

BERTE PROCESS. A printing process typified by flat, brilliant water colours on a matt paper. The colours may be overprinted as desired, and a coarse medium can be introduced. It is customary to use non-metallic blocks, such as rubber, linoleum and many synthetic materials. See WATER-COLOUR INK.

BERYL, see BERYLLIUM.

BERYLLIUM (Be). Atomic no. 4; atomic wt. 9.02; hard, white, metal obtained from beryl and other minerals. Density 1·84; m.p. 1825 deg. C. In its chemical properties it resembles magnesium and calcium; it is divalent, forming an oxide BeO. Some light alloys contain a proportion of beryllium. Beryl is a beryllium aluminium silicate, $Al_2Be_3Si_6O_{18}$; the purest specimens of this mineral are the gem stones, emeralds.

BESSEMER PROCESS. The process of making steel by refining pig iron in a Bessemer converter. Two modifications of the process are used. In the "acid" process, the converter is lined with siliceous materials; phosphorus is not removed and the pig irons used must therefore contain little of this element. In the "basic" process, the converter is lined with a basic material such as dolomite. The

pig irons used may contain considerable quantities of phosphorus since this is largely eliminated. In either process, the converter consists of a pear-shaped vessel, open at the top and provided with holes at the bottom to admit air at a pressure of about 20 lb. per sq. in. The converter is turned on its side and molten pig iron poured in; the blast is put on and the converter righted.

In the acid process, however, the impurities, carbon, silicon and manganese, burn rapidly, generating a considerable quantity of heat which raises the temperature of the charge. The carbon is converted to carbon monoxide which burns with a large blue flame at the mouth of the converter. The disappearance of this flame signals the end of the blow. The air is at once shut off and the converter turned on its side. The charge is deoxidized, and the requisite amount of carbon introduced, by addition of ferro-manganese or spiegel. The complete process takes 12 to 18 minutes.

The basic steel-making process is operated on the same general lines, but after the drop of the flame the blow must be continued for 5 to 10 minutes to eliminate phosphorus. The slag containing most of the phosphorus must be removed before the charge is deoxidized or phosphorus

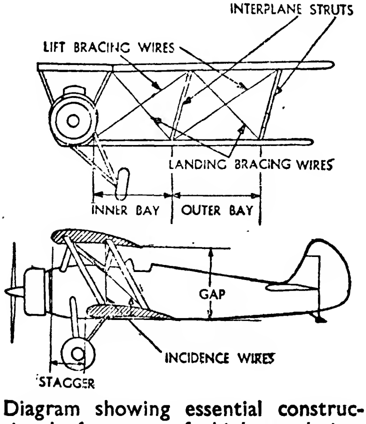


Diagram showing essential constructional features of biplane design.

may be returned to the melt. Steel of excellent quality can be made by either process.

BIAS, see GRID BIAS.

BIB COCK. A tap for drawing water, usually placed over a sink or similar fitment. The outlet, or nose, is in the form of a bib, and the construction is similar to that of a stop cock (q.v.). For hot water a fibre, rubber or patent washer should be used.

BIDET. A sanitary appliance for washing the lower parts of the body. The general type has a mixing valve directing hot, cold or tepid water to the ascending spray or flushing rim. Bidets should be trapped on the outgo to the waste pipe in the same manner as sinks.

BILLET. A term sometimes used in the metal industries to denote the rolled product destined for pressing or forging. Surface defects in large billets are removed by a wide variety of methods, including pneumatic-hammer chipping, mechanical chipping, scarfing and grinding. The oxy-acetylene torch may also be used for descaling purposes, this principle having proved very successful with large slabs used in continuous-sheet rolling. Modern furnaces for the reheating of billets have achieved a high degree of efficiency, one of the latest examples being designed to take 17 insulated trays 5×2 ft. on which the billets are loaded. These trays are moved through the furnace by mechanical pushers, and the discharging mechanism is so arranged that when the press operator requires a heated billet he presses a button which causes one to be discharged on to a conveyor leading to the press. The heating and soaking time is $1\frac{1}{2}$ to 2 hours. See CONTINUOUS ROLLING.

BILLIAN, see IRONWOOD.

BILL OF QUANTITIES. A schedule setting out the quantity of materials and amount of labour comprised in a building or engineering works contract so that the cost can be estimated. Its preparation comprises the following processes :—

(1) *Taking-off* the measurement of all items shown on the architect's

drawings and described in the specifications;

(2) *Abstracting* and squaring the dimensions from the taking-off sheets and setting them out in the form of a bill, the trades being grouped in order of sequence; and

(3) *Billing* or casting-up the items shown on the abstract, and reducing and transfering the totals to a pricing-sheet.

BINDERS, see DOUBLE FLOOR and FLOORING.

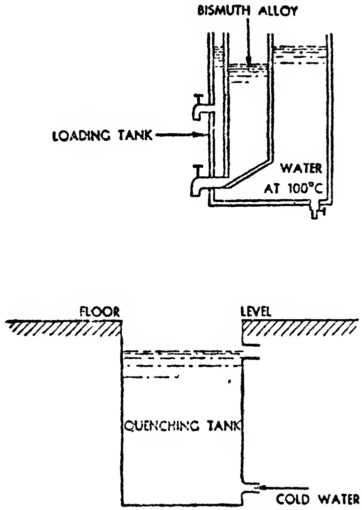
BIPLANE. An aircraft having two main planes one above the other. Nearly all biplanes are braced, either by struts or bracing wires, although cantilever biplanes have been built. The salient features of biplane construction are indicated in the accompanying illustration. The gap between the top and bottom planes of a biplane is usually about equal to the chord. The biplane has a lighter wing structure than the corresponding monoplane, but suffers from the drag of the bracing wires, struts etc. The equivalent monoplane span of a biplane is the span of that monoplane which, having the same total wing area as the biplane, would have the same induced-drag characteristics. Many biplanes have folding wings for ease of storage, and in such cases a jury strut is fitted between the front spars of the top and bottom planes when the wings are folded in order to resist the tension of the bracing wires.

BIRCH. A light-brown lustrous wood, fairly hard, tough and strong, but not durable for exterior work. The fine, even grain retains sharp arrises. It stains and polishes well and is used for fittings, turnery, hand-rails etc. Birch is grown mainly in Europe and Canada; species from Canada provide a more decorative wood, esteemed for superior joinery. See TIMBER.

BIRD'S-MOUTH JOINT, see JOINTS.

BILLING, see BILL OF QUANTITIES.

BISMUTH (Bi). Atomic no., 83; atomic wt., 209·0; density, 9·8; m.p. 271 deg. C.; b.p., 1,450 deg. C. A brittle metal of pinkish-silvery



Arrangement of hot- and cold-water tanks for bending large quantities of tubing by means of bismuth alloy.

colour, it is trivalent bismuth trichloride, $BiCl_3$, and bismuth trioxide, Bi_2O_3. Bismuth citrate and other bismuth salts are used in medicine.

Bismuth (Brinell hardness 7·3) has the property of expanding during solidification by 3·32 per cent of its solid volume at the melting-point. It alloys freely with such common metals as antimony, arsenic, cadmium, tin, lead, silver, gold etc. and is considered the most diamagnetic of all metals, i.e. a suspended bismuth rod tends to sit at right-angles to a magnetic field. Other interesting properties of bismuth are that thermal conductivity decreases in the magnetic field, while electrical resistance increases. The metal is absorptive to X-rays; its specific resistance is 106·5 microhm-centimetres at 0 deg. C., 267 microhm-centimetres at melting-point, and 127 microhm-centimetres in the liquid state. The mean coefficient of thermal expansion from 0 to 100 deg. C. is 0·00000731.

The principal uses of bismuth metal are for thermocouples, pyrometers etc., and for instruments for determining strength of magnetic

fields. The chief uses of the alloys are: for low-melting-point solders, fusible alloys for safety plugs, etc., low-melting-point alloys of extreme fluidity and setting expansion for accurate pattern casting, expanding fillers for bending tubing and open sections, hard-setting matrices with setting expansion for press-tool mounting, jig-assemblies, and sheet-forming dies.

These alloys usually contain about 50 per cent of bismuth, about 25 to 30 per cent of lead and about 20 per cent of tin. One such alloy, Wood's metal, melts at 71 deg. C., while Rose's metal, an alloy of 50 per cent bismuth, 27 per cent lead and 23 per cent tin, melts at 95 deg. C.

One way in which the properties of bismuth are used in metal-forming is in the process of bending thin-walled tubes. For this purpose an alloy of bismuth, lead, tin and cadmium is used, having a melting point of 160 deg. F. Throughout the operation no temperature higher than that of boiling water is used. Since the alloy has a setting expansion of approximately 0·006 in. per in., the tube walls are held in actual tension. After bending, the alloy is easily removed by plunging the formed tube in boiling water, when the filler will completely drain out. Should any minute drops of filler remain, they can be removed easily by subsequently plunging the tube in cold water, the beads of filler then being swept off by a pull-through.

When the alloy is being used for this purpose, it is first put in a clean ladle and covered with water. The ladle is then heated until the water is at boiling-point and the alloy completely melted. The boiling water is poured off the top of the ladle into the tube, which has previously been oiled internally with a fairly thin machine oil and closed tightly at one end with a cork or hardwood stopper. The molten alloy is now poured into the tube, displacing the lighter water, and when the tube is filled it is at once plunged, corked end first, into cold water to effect rapid solidification. Bending of the tube must not be attempted until room temperature is reached. For handling large batches of tubing on continuous-production work, a permanent arrangement of hot- and cold-water tanks is desirable; these should be of the type illustrated.

BITUMEN. Mineral pitch or asphalt, a complex hydrocarbon originating from vegetable growths of remote ages. It may accur naturally or be obtained during the distillation of petroleum. In ordinary temperatures it is a somewhat brittle solid which, with slight increase in temperature, becomes plastic; at slightly higher temperatures it liquefies. In the latter state it is used by painters for weather-proofing roofs, external brickwork etc., either alone or in combination with gas-tar.

Bitumen is readily soluble in the media used for oil painting and itself exerts a solvent action upon them. Consequently, superimposed paint is softened and eventually becomes discoloured; to prevent this, a film ot shellac is placed between the bitumen and the paint. Bitumastic paints which possess special weather-resisting properties are manufactured, but are somewhat restricted in their range of colour. Bitumen is one of the main ingredients in black japan, a type of black varnish made to stand the heat of stoving, for use upon the ironwork of vehicles, and for backing-up the gold leaf in gilding (q.v.) upon glass.

BLACKBUTT, see EUCALYPTUS.

BLACKING. A mixture of fixed carbon, coke or coal dust and plumbago. Mixed with thin clay-wash and a small amount of core gum, it is used to coat the faces of dry-sand cores or moulds to prevent fusion and penetration of the sand by the hot metal. Blacking may be applied either before or after drying the mould as is most convenient. Green-sand moulds may be coated with the dry powder. Blacking is also used as an ingredient in green sand.

BLACK LEAD, see GRAPHITE.

BLANC FIXE. A fine, white pigment used to coat paper; it consists of

finely-divided precipitated barium sulphate. See BARIUM.

BLANKHOLDER. A device used in operations of drawing metal, generally on a double-action press, to ensure that the blank is firmly seated and held while the drawing punch continues its downward movement. The punch may be located inside the blankholder, which can be fitted with a rubber pressure pad or strong spring. When a flat blank is held by the blankholder, no wrinkles will form if the die is properly constructed, all movement being radially inwards if a cylindrical shape is being drawn. Large presses hold the blanks by means of separate toggle levers or by hydraulic-jack rams, which give a controlled pressure and release action.

BLANKING, see POWER PRESS AND PUNCHING MACHINE.

BLAST-FURNACE. A cylindrical or slightly conical shaft furnace used for smelting iron-ore in the production of pig-iron. It consists, as shown in the accompanying diagram, of a sheet-metal casing lined to a thickness of about three feet with refractory materials.

These furnaces are usually charged with coke, iron-ore and limestone. An air blast, introduced through tuyeres, or nozzles, near the bottom of the furnace, is used to burn part of the coke, so maintaining the charge at a high temperature. The remainder of the coke reacts with the iron-ore reducing it to metal which collects in the well of the furnace. The limestone forms a fluid slag with the earthy impurities in the ore and the ash derived from the coke. The slag collects on the top of the liquid metal in the well where it can be run off as required. The exhaust gas, containing as it does a considerable proportion of carbon-monoxide, is valuable as a fuel. It is used partly for pre-heating the air blast, so improving the thermal efficiency of the furnace, and partly as a substitute for town gas.

Blast-furnaces are operated continuously for long periods, pig-iron being drawn off from the well at regular intervals. The iron is run into

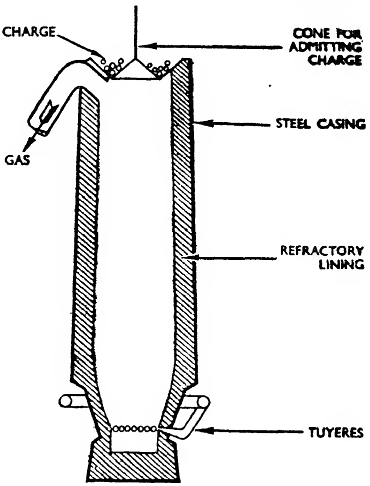


Diagram showing main components of a blast furnace as used in smelting iron-ore and for producing pig-iron.

pig-beds or into chill-moulds carried on a conveyor belt. The iron produced contains 3 to 4 per cent of carbon, together with varying proportions of the impurities silicon, sulphur, phosphorus and manganese, depending on the grade and type of ore used.

BLAST-FURNACE GAS, see FUELS.

BLEED. A term used in printing when an illustration is so arranged that it runs off into the margin, extending to the edge of a page. Conversely, in bookbinding, to overcut the margins and mutilate the printing.

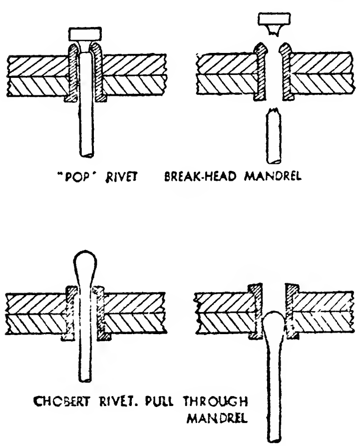
BLEEDING (Painting). The penetrative action of tar-like substances upon the oil contained in superimposed paint and consequent discoloration of the surface; pigments derived from coal-tar dyes were formerly liable to this defect. The resinous secretions of various timbers also develop this condition. All surfaces which are suspect should receive a preliminary treatment of a thin coating of shellac.

BLIND LANDING. A radio system enabling an aircraft to land easily under conditions of poor or zero visibility. The Lorenz system is one

of the best known and it, like others, provides the pilot with the necessary information.

One signal from a transmitter gives directional guidance, enabling planes to head straight to the aerodrome and to land in the centre of the runway; another signal gives vertical guidance enabling the pilot to decide what is the required angle of glide.

BLIND RIVETING. A process by means of which two pieces of sheet-metal may be riveted together when access is possible from one side only. The rivets, hollow or tubular in form, are threaded on a shaped wire mandrel, which is pushed through the holes in both sheets and then withdrawn. The act of withdrawing the mandrel burrs-over the end of the



Chief types of rivet widely used in the blind-riveting process.

rivet and causes it to grip the surrounding metal. Several different types of rivet are made for this process but chief among them are the pop and Chobert rivets as illustrated above.

BLISTERING. The term used to describe the action upon the plane surface of paint when broken by bulges, hemispherical in form. This may usually be ascribed to moisture imprisoned by the elastic paint-film being vapourized by heat; the painting of damp and unseasoned timber is the most general cause, but blistering may occur upon any type of surface which has been painted during damp and frosty weather. Paint upon pitch-pine in sunny positions is very liable to this defect. The use of old fat-paint may also be a contributory cause.

BLOCK. A general term for a printing plate used in the letterpress process. Blocks for illustrations may be line or half-tone, or a combination of both. A line block is one which reproduces its subject in black and white lines only, with no intermediate tones; a half-tone block gives a photographic effect having many shades between the darkest and lightest portions. Letterpress blocks are usually thin plates of zinc for line work, while half-tone blocks are usually of copper. Both line and half-tone blocks are usually mounted on wood to bring them up to type height.

BLOCKBOARD, see LAMINATED BOARD.

BLOOMING (Painting). A whitish condition within a film of varnish, similar to the bloom upon ripe stone fruit, caused by the absorption of moisture by the varnish before it was hard dry. Varnishing under humid weather conditions, applying warm varnish upon a cold surface, cold draughts and frost upon the wet film, are all conditions which may cause condensation and be the reason for the disfigurement.

BLOOMING MILL (Metallurgy). A mill which imposes the first deformation on the ingot in continuous-rolling; also known as the slabbing mill. Ingots are delivered from the soaking pits to the approach table by means of a remote-controlled motor-operated ingot buggy, which has a tilting pawl-and-cam arrangement to effect automatic delivery of the hot ingot. The mill is usually of the two-high reversing type, and the complete operation—including screwdown, slab-squeezing, edge-passing, and delivery to the slab shears—is controlled from a pulpit on the entry side of the mill. When rolling is complete at this stage, the metal is in slab form.

BLOWLAMP. A lamp much used by electricians, plumbers, painters etc., for jobs requiring a hot, clean flame and comparatively high concentration of heat. The type in general favour, shown in the illustration, is the paraffin lamp, which has a small pump in the body, or reservoir, for raising the necessary air pressure to force the fuel through a small orifice. The petrol type has no pump, the fuel being sufficiently volatile to make atomization more or less automatic.

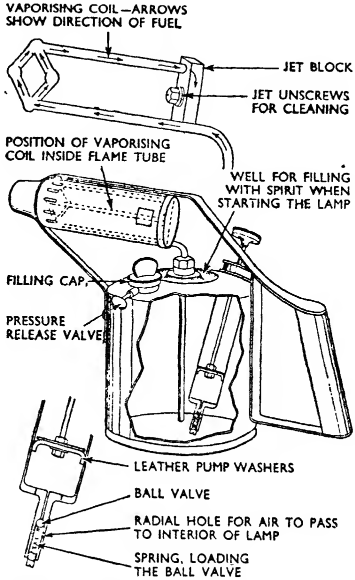
It should be noted that it is both wasteful and dangerous to use petrol in the paraffin type. Large blowlamps are used for brazing and similar work, while there is a type made for starting purposes on diesel engines.

The medium-sized paraffin blowlamp is used as follows:—The reservoir is first filled with paraffin and the stopper screwed down until it makes an air-tight fitting. Methylated spirit is now poured into the channel below the burner and ignited, the object being to warm the coiled pipe of the burner to assist in vaporizing the fuel. When this is judged to be warm enough, the pump is used to raise the pressure of the air in the space above the paraffin. The fuel should now hiss from the burner in the form of vapour and, on being lighted, should give a short, reddish-violet flame. If the lighted paraffin spurts out in a long thin jet the fuel is too cold, and the pressure must be released by unscrewing the stopper. During use, air should occasionally be pumped in to keep up the pressure.

BLOWN LINSEED OIL, see LINSEED OIL.

BLOW-OUT COIL. A coil whose magnetic field is so disposed relative to a pair of contacts that the arc produced when the contacts open is elongated and extinguished. An arc behaves in a magnetic field as though it were a flexible current-carrying conductor.

BLOWPIPE. A device for mixing oxygen with some combustible gas, usually acetylene, to provide a mixture suitable for the production of a high-temperature flame. A blowpipe usually consists of a valve body provided with two regulating valves, one for oxygen and one for the inflammable gas, with which the supply of each gas to the mixer is adjusted. The



Diagrammatic illustration of working principles of the paraffin blowlamp.

gases pass from the valves via the mixer to a tubular neck or extension, on the end of which is fitted the nozzle through which the mixture issues.

BLUE. A primary colour, made from pigments obtained from vegetable, mineral and artificial substances. See CHINESE BLUE, MONASTRAL BLUE, PRUSSIAN BLUE and ULTRAMARINE.

BLUE GLOW. A visible indication that a thermionic valve is "soft" that is, that it has lost some of its hard vacuum and contains a trace of gas, usually oxygen. The passage of electrons from cathode to anode ionizes this gas, which exhibits a characteristic glow. While this condition usually indicates that the valve is faulty, it should be borne in mind that certain tubes are intentionally filled with inert gas, in which case a

glow is a normal condition. Mercury-vapour rectifiers and gas-filled relays, or thyratrons (q.v.) belong to this class.

BOARD OF TRADE UNIT. The practical unit of electrical energy, or the kilowatt-hour. The words Board of Trade are usually omitted. A one-kilowatt heater consumes one unit per hour, a two-kilowatt heater two units per hour, and similarly for other ratings.

BOILED OIL (Painting). Linseed oil which has been heated with the addition of driers, usually to a temperature above 400 deg. F. It is slightly darker and thicker than refined linseed oil, and is used as a slow-drying thinning medium for paints and printing inks. Inferior qualities have liquid drier added to the oil, and the heating is omitted.

BOILER. An open or closed vessel in which a liquid can be brought to its boiling-point. The boiling-point of a liquid varies with its pressure (above or below atmospheric pressure), but is usually given as the boiling-point at normal atmospheric pressure. Boilers for hot water and central heating are discussed under HOT-WATER SYSTEM.

The steam boiler, or steam generator, is a closed vessel in which water can be raised to a temperature above that of its normal boiling-point, with the consequent production of steam at a pressure above that of the atmosphere. Boilers may be divided into two main types: (1) fire-tube, and (2) water-tube. In the former the fire is led through the tubes and the water circulates around them, whereas in the latter the fire heats the tube, which contains the water. Locomotive boilers are an example of the fire-tube type, while marine installations usually follow the water-tube principle. Tube boilers can be built with one or two large flues or be multi-tubular. The

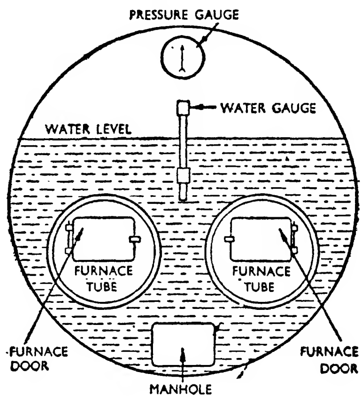
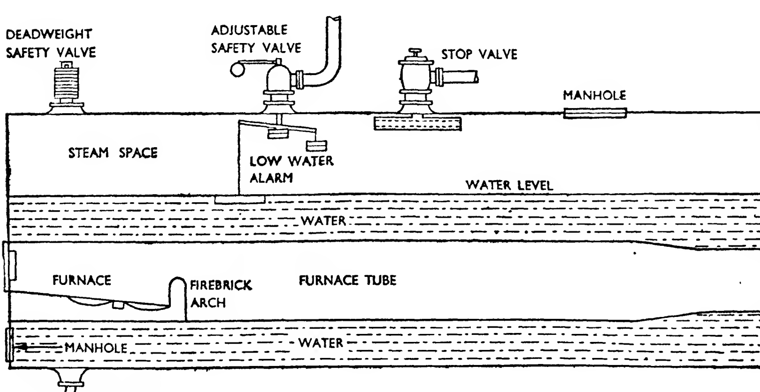
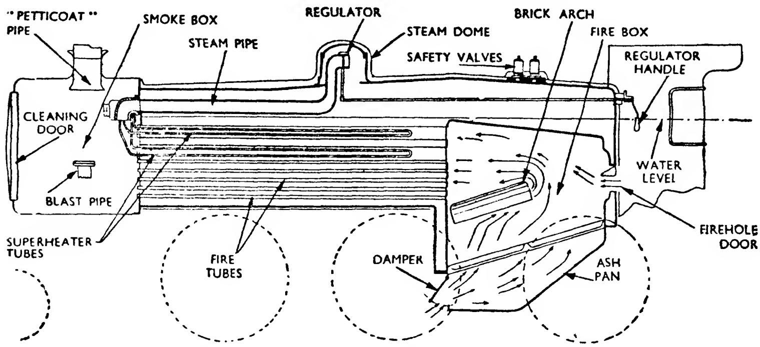


Fig. 1. (Above). Furnace-end view of a Lancashire boiler. Note two furnaces.



SIDE VIEW OF LANCASHIRE BOILER

Fig. 2. Horizontal stationary boilers such as this are widely used in industrial plants. The usual size of a Lancashire boiler is: length 30 ft. and diameter 8 ft.



DETAILS OF TYPICAL LOCOMOTIVE BOILER

Fig. 3. Smoke-box, barrel and fire-box comprise the three main parts. Superheater tubes are accommodated either in the smoke box, or, as shown here, in the boiler.

latter are more efficient as regards rapid steaming, owing to the large heating area presented by a number of small tubes in comparison with the volume of water contained. Multi-tubular boilers are also much stronger (greater strength-to-weight ratio) as the small, solid-drawn tubes can be much thinner in wall section than large tubes withstanding the same pressure. They are therefore coming more and more into use with the modern tendency to employ extremely high pressures. Further, in the event of a fracture of one small tube, the danger is not so great as it would be in a large, cylindrical-type boiler.

FIRE-TUBE BOILERS. Cornish, Galloway and Lancashire boilers are all examples of the fire-tube type in which, as distinct from the locomotive boiler, the flues are large and few in number. In the Cornish boiler there is only one flue, usually of three-fifths the diameter of the main drum. In the Lancashire boiler there are two flues placed side by side, each of two-fifths the diameter of the main drum. At the furnace end a convenient length of the flue acts as the fire-box, being provided with fire-bars and a brick arch to assist in complete combustion. Fig. 1 shows an end view, and Fig. 2 a side view, of a Lancashire boiler.

The Galloway boiler is very similar to the Lancashire and Cornish boilers save that cross-tubes are placed in the main flues, giving greater heating area and greater strength. These tubes are called Galloway tubes after their inventor.

Fig. 3 shows the type of multi-tubular boiler and furnace details as applied to locomotives, the chief necessities being compactness and a low centre of gravity. Forced draught is obtained by means of a steam jet in the smoke box, to which either the exhaust steam from the cylinders, or steam from the boiler, is admitted under the control of the driver.

WATER-TUBE BOILERS. One type of water-tube boiler is the Babcock and Wilcox, a sectional view of which is shown in Fig. 4. In this a bank of sloping, weldless steel tubes is suspended from the main water-drum within a brick furnace, the suspension allowing greater freedom for expansion and contraction than would be the case if they were held rigidly. Cold water from the drum sinks to the lowest point and rises up the sloping tubes, thus maintaining a steady and rapid circulation.

It is customary for baffle plates to be introduced in the furnace to cause the gases of combustion to flow at right-angles to the tubes, up and down throughout their length.

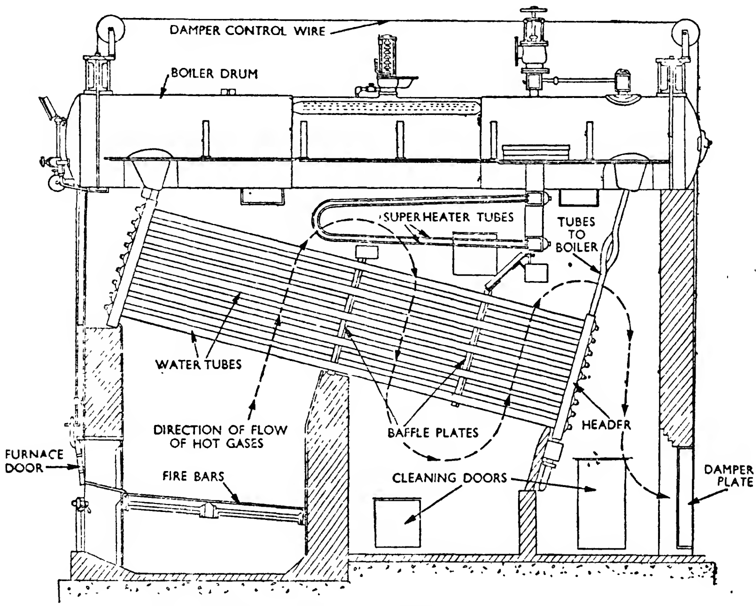
Other types of water-tube boiler employ two or more main drums, the tubes sloping sharply from the lower to the upper drums. In all types the

circulation arrangement follows roughly the shape of a letter U.

A form of water-tube boiler which is useful in certain circumstances, for the rapid provision of steam as required where the service is intermittent, is the flash boiler. This contains little or no water until fed as required by the force-feed pump. It usually takes the form of a coiled tube, or series of coils, capable of withstanding great heat, into which water is pumped at one end and delivered as steam at the other. High pressures can be maintained, and there is little danger of explosion, the quantity of steam within the boiler at any moment being very small.

VERTICAL OR HORIZONTAL BOILERS. A simple vertical boiler is illustrated in Fig. 5. This consists of an outer shell of riveted steel plates, heavily lagged to prevent loss of heat by radiation. Within the shell is a fire-box or chamber surrounded by water. The fire-box contains the furnace and also one cross-water tube, the object of which is to increase the heating area and so improve the circulation. At the top is the uptake by which the products of combustion pass to the chimney, while the furnace door and fire-bars are placed conveniently just above the air intake at the bottom. This type of boiler is well suited to the production of steam for small power units, but is wasteful of fuel in large sizes owing to the fact that the gases of combustion pass too rapidly to the atmosphere, before they have given up their full heat, or sufficient proportion of their heat, to the water.

More efficient in this respect, however, is the Scotch boiler, also vertical, illustrated in Fig. 6. In this the hot gases are led horizontally through the water by a number of smaller tubes to the uptake, thereby being retarded in their escape and



SECTIONAL VIEW OF WATER-TUBE BOILER

Fig. 4. Weldless steel tubes, sloping from the front of boiler towards the back, allow the water to circulate freely. The whole assembly is enclosed in a brick chamber, provision being made at the back for receiving the products of combustion.

remaining longer in a position to give up useful heat.

The illustrations of the Lancashire and locomotive boilers, Figs. 1, 2 and 3, show two well-known horizontal types.

In addition to the main parts of a pressure boiler, the cylinder, tubes and fire-box, there are a number of indispensible accessories. These are: (1) pressure gauge, (2) water gauge, (3) safety valve and (4) feed-water pump or injector.

The feed-water pump is for supplying water to the boiler while it is working. Not many boilers contain enough water for more than a few minutes' steam supply to the engine, and fresh water must therefore be in constant supply, from a storage tank or the hot well of the condenser. Any type of plunger or rotary pump will serve the purpose, but it is desirable that the supply shall be steady and regular. A superheater, although not a necessary adjunct, is nearly always included in modern boilers to dry the steam, thus avoiding the use of a separator. Forced-draught steam economizers and automatic stokers may also be included, save, in the last case, where oil-firing is employed.

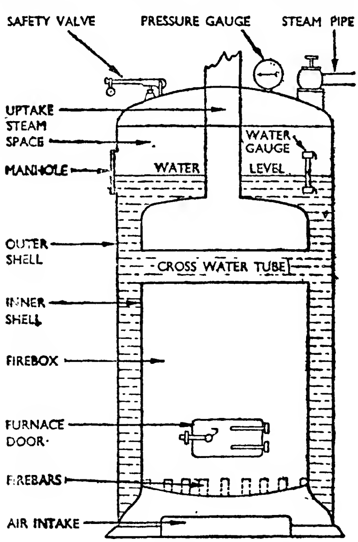


Fig. 5. Simple boiler of the vertical type which can be adapted for use with small engines and in restricted space.

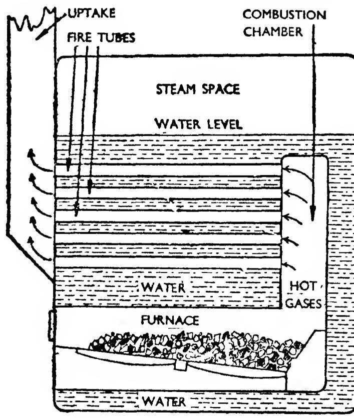


Fig. 6. Multi-tubular cylindrical boiler which is also known as a Scotch boiler.

BOILING-POINT (b.p.). The degree of temperature at which, under some defined pressure, a liquid is continuously transformed into vapour; in other words, the temperature at which the vapour pressure of the liquid reaches the pressure of the surrounding gas or vapour. The presence of a dissolved substance raises the boiling-point of a liquid, and the rise of the boiling-point of a solution depends on the concentration and molecular weight of the substance dissolved.

BOLSTER. A steel chisel with a cutting edge four inches long (Fig. 1).

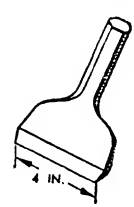


Fig. 1. In the equipment of a bricklayer, an implement such as this, resembling a wide steel chisel and known as a bolster, is essential.

used in conjunction with the hammer for snapping or cutting brickwork.

Also, in sheet-metal work, a press-tool attachment for holding a die in position on the press bed (Fig. 2). Its principal functions are to provide

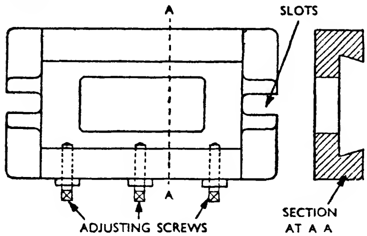
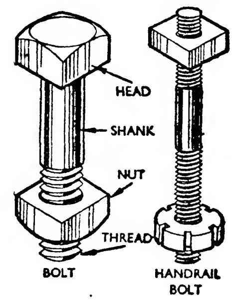


Fig. 2. Diagram showing a bolster used to hold a die in position.

adequate support for the tools, to hold them in their proper position relative to each other, and to provide an attachment to the press bed. The die can usually be located in the bolster by adjusting- or locking-screws acting against the die to hold it against a solid face as in a vice or against a taper vee edge. Taper keys are an alternative to screw setting. Correct design is important, as success or failure of a die set may often depend upon adequate support or accurate alignment of the bolster. Cast-iron, cast-steel, and mild-steel bolsters are used, the last two being preferable.

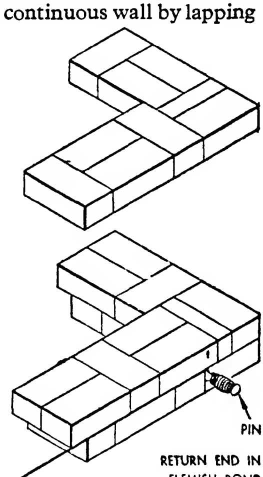
BOLT. A cylindrical metal rod, threaded at one end to take a nut, and having a head at the other. A nut and bolt together form the most common means of fastening two parts together. The type generally used for woodwork has a square head as shown, but there are other varieties such as snap, pan, hexagonal etc. Handrail bolts, as seen in the illustration, are used for securing an end-to-end joint, as in mitres, handrails etc., and have the

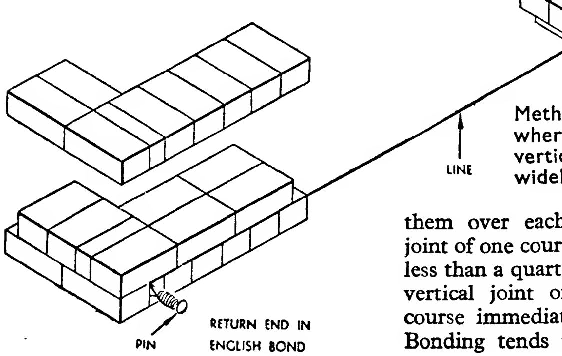
Two types of bolt (right) widely used in woodwork for fastening two parts together. The handrail type is used only in special cases, as is explained in the text.



advantage that, when assembled, they are invisible. The rod passes through holes in each member and the square nut at one end of the bolt is fitted into a square mortise; the nut at the other end is circular and has notches cut into its periphery to enable it to be screwed-up in its mortise. For this purpose a *hand-rail punch* is used.

BOND. The arrangement and massing of bricks in such a manner as to make them into a continuous wall by lapping





Method of laying bricks whereby overlapping of vertical joints is avoided ; widely known as a bond.

them over each other. No vertical joint of one course of bricks should be less than a quarter of a brick from the vertical joint of the bricks in the course immediately above or below. Bonding tends to unite the various

parts of a wall, thus equalizing the strength of the bearing surface throughout the length of the wall. The principal kinds of bond are:

(1) *English bond*, consisting of alternate courses of headers and stretchers;

(2) *Flemish bond* (*double*), consisting of headers and stretchers in the same course and on both sides of a wall;

(3) *Flemish bond* (*single*), consisting of headers and stretchers in each course on the outside face of the wall and alternate courses of headers and stretchers on the inside face of the wall.

There are many modifications of the ordinary bonds such as *stretching* bond; *heading* bond; *garden-wall* bond; and *Quetta* bond. See CLOSER.

BONDERIZING. A proprietary phosphate-coating process (British Patent Nos. 270679 etc.) consisting of the immersion of iron or steel articles in a boiling solution of an acid metal phosphate, e.g. zinc dihydrogen phosphate, with or without the addition of small amounts of accelerators to speed-up the formation of the coating. The coating consists of a thin greyish film of insoluble metal phosphates, which, although having relatively small corrosion-resistance in itself, greatly improves the adhesion and protective value of paints or lacquers applied over it.

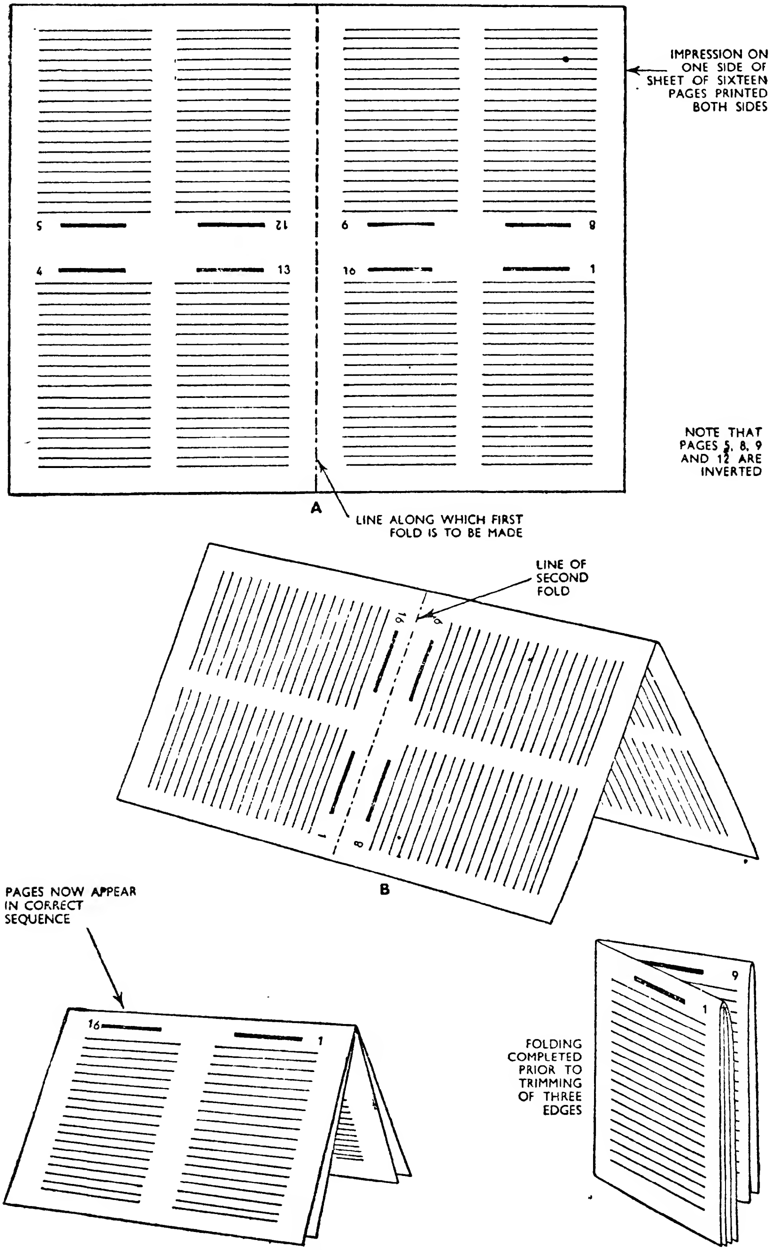
Bonderizing, although a similar process to Parkerizing (q.v.), differs from the latter in that the film is finer grained and smoother, and the processing time much shorter (3 to 7 minutes). It is therefore especially suitable for use as a pre-treatment before painting. In the spray Bonderizing process, the parts to be treated are not immersed in the hot solution, but the latter is circulated by a pump and continuously sprayed on to them by a series of jets as they pass through a tunnel on a conveyor. The spray Bonderizing process is well adapted to mass-production methods.

BONDING. The operation of connecting together all metal parts of an aircraft by means of thin copper strips and braided wire. The main purpose is to ensure that all metal parts are at the same electric potential, thus eliminating interference with wireless reception and transmission. For the same reason ignition systems of aero. engines are shielded by enclosing magnetos and cables in metal covers earthed to the aircraft bonding system.

BOOKBINDING. The process by which separate sheets of paper or similar material are converted into a handy and more or less permanent form. With printed books, the pages, or areas of type, are received by the bookbinder from the printer as flat sheets, each containing a specified number of pages, which are so arranged on the sheet that when it is folded in a certain way the pages are in correct sequence. This necessitates the sheet being printed on both sides, and some of the pages being upside down.

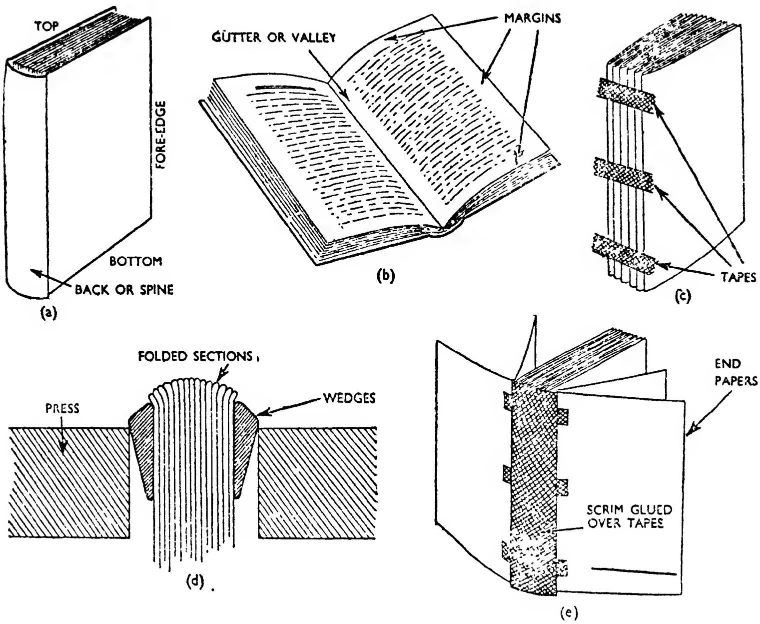
To the printer, this arrangement of the pages on the sheet is known as an imposition, and the imposition must be arranged to suit the method of folding. A simple imposition of 16 pages is shown in Fig. 1 (a), but there may be on one sheet any number in multiples of 8, usually 64 or 128. Where there are 128, the sheet is usually cut in half and folded as a 64. The type of imposition shown in the illustration would necessitate the sheet being folded first vertically down the middle, then horizontally, and finally vertically again. The pages will now be in correct order and sequence, with wide margins as required, and, when cut along the top, bottom and fore-edge, will become a section of 16 pages in 4 folders. To assist in getting a number of sections in sequence, the printer places a signature on each sheet, consisting of a symbol or a number. This practice has given rise to the custom of calling sheets or sections "signatures."

The collected and collated sections are now sewn in the folds with strong linen thread on to tapes placed across the back as in Fig. (2c), the sewing nowadays being done by machinery. The sewing, however, causes the back



TYPICAL IMPOSITION FOR SIXTEEN PAGES

Fig. 1. So that the sixteen pages imposed on a sheet will fall in the correct order for binding, they are laid-out in the order indicated and the sheet folded as shown.



METHOD OF BINDING SECTIONS OF A BOOK

Fig. 2. Diagram illustrating the various stages in the bookbinding process. The chief terms are shown, as applied to various parts of a book (a) and to a printed page (b).

of the book to swell, so it is next placed in a press with backboards (see Fig. 2(d)) and nipped, the folded edges being turned over left and right of the centre to make for ease of opening. Now a length of scrim, (Fig. 2(e)) about an inch wider than the back, can be glued over the tapes and sewing, after which the end papers are glued on. These are folders of tougher paper than the rest so attached to the first and last sections of the book that one page of the folder acts as a blank page while the other can be glued down, over the edge of the scrim, to the cover. Further linings on the back can be added if desired.

The foregoing processes are known as *forwarding*. *Finishing* originally meant the work of lettering and ornamentation on the cover, but modern covers are made beforehand, already lettered and ornamented, and supplied as cases into which the book can be inserted. These cases are made of strawboard covered with varying grades of cloth, and are attached to the book by means of glue or paste, partly to the edges of scrim projecting on each side of the back and partly to the end papers. The final process consists of placing the finished book in a press to keep it from curling as it dries.

A full-bound book is one that is covered entirely with the material stated, usually leather or something more lasting than cloth; a half-bound book is one that has leather spine and corners, with cloth in between; and a quarter-bound book is one that merely has the spine of one material and the edge of another.

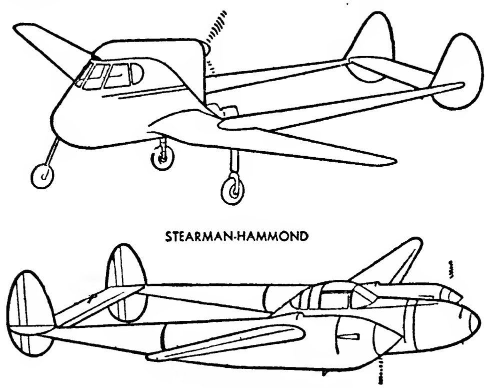
Book sizes depend chiefly on paper sizes. For example, double crown paper, which is 20 × 30 in., if folded twice each way, will give sections, before cutting, of $7\frac{1}{2} \times 5$ in. This is roughly the size of crown octavo, although it should be noted that the

various names given to books indicate more the proportions than the actual sizes. The more important sizes are:—

Foolscap Octavo	..	6¾ in.	×	4¼ in.
,, Quarto	..	8½ ,,	×	6¾ ,,
Crown Octavo	..	7½ ,,	×	5 ,,
,, Quarto	..	10 ,,	×	7½ ,,
Demy Octavo	..	8¾ ,,	×	5½ ,,
,, Quarto	..	11 ,,	×	8¾ ,,
Medium Octavo	..	9½ ,,	×	6 ,,
,, Quarto	..	12 ,,	×	9½ ,,
Imperial Octavo	..	11 ,,	×	7½ ,,
,, Quarto	..	15 ,,	×	11 ,,

Octavo, usually written 8vo, is obtained by folding a full sheet 3 times, thus producing 8 leaves or 16 pages; quarto, usually written 4to, is obtained by folding a full sheet twice, thus producing 4 leaves or 8 pages.

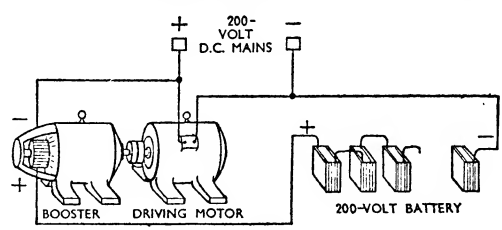
BOOM. A beam or spar. In some aircraft designs, twin booms are frequently used to support the tail unit when, as in the case of a single-engined pusher, it is not possible to have a normal fuselage extending aft of the wing, the booms being attached to the wing on each side of the aircraft centre line. Two examples are illustrated on the left.



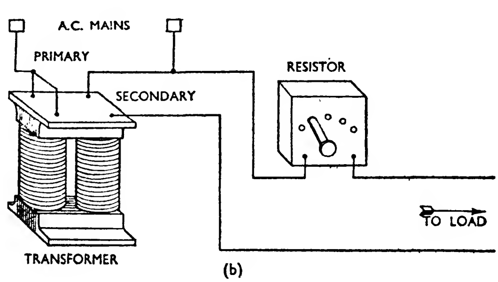
In certain aircraft designs two booms are sometimes used to carry the entire tail unit.

BOOST. The amount by which the pressure of the petrol-air mixture in the induction manifold of a supercharged aero engine exceeds normal sea-level atmospheric pressure. In Great Britain, the common unit of measurement is pounds per square inch. Boost is measured on a boost gauge mounted on the pilot's instrument panel, the manifold pressure being transmitted to the

Shown below is a D.C. booster (a) assisting mains to charge a battery; the connexions are such that the voltages add. The transformer (b) is used to increase the mains voltage, as explained on the opposite page, by connecting its low-voltage secondary in series with the mains. The resulting voltage is cut-down as necessary by an appropriate variable condenser.



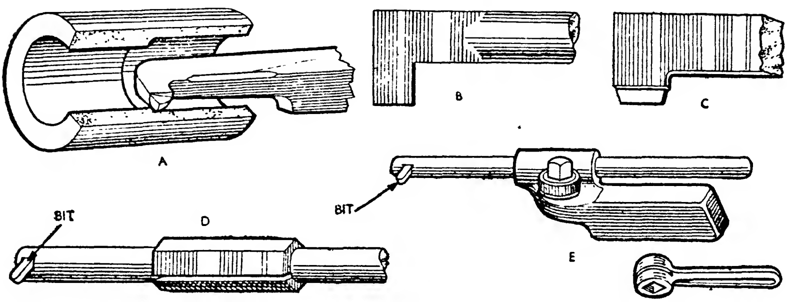
(a)



(b)

gauge by a pipeline. In the U.S.A. and on the Continent, aircraft are usually fitted with a gauge which measures the absolute induction-manifold pressure in inches of mercury.

BOOSTER. An electrical generator or transformer, series-connected in a circuit to increase the voltage. Decreasing the voltage, which is known as *bucking*, may also be performed by a booster. The diagram shows (a) the connexions of a D.C. booster and (b) the use of an A.C. booster for voltage control. See TRANSFORMER.



BORING TOOLS AND HOLDERS

In mechanical engineering various types of boring tool are widely used for increasing the internal diameter of a hole after drilling. In the above diagram are shown : *A* solid forged boring tool ; *B* square-nosed boring tool ; *C* recessing tool ; *D* boring tool holder of round bar, with split hexagonal bar clamps to enable lathe tool to exert grip, and *E* adjustable boring-tool holder with detachable wrench.

BORAX, see BORON.

BORE. The internal wall of that part of a cylinder or a pump barrel within which the piston travels; the hole which runs along the axis of a pipe or gun barrel. The diameter of such a hole, usually measured in millimetres, is sometimes referred to as the bore.

BORING. In engineering, the process of opening out a hole to a larger internal diameter after it has been drilled ; or, in woodwork the actual drilling of the hole. Although the engineer's reason may be merely that the correct size of drill or reamer is not available boring is dictated rather by the need for a correctly centred and true-running hole. The correct setting of the workpieces on the face-plate, or in the chuck, is thus of special importance. The tools used in boring differ from those used in ordinary turning. The cutting edge is turned round so as to face the operator, giving the effect of a tool cutting from left to right; it is not perpendicular to the axis of the work, but is turned to an angle of about 20 deg. to it, so as to cause the chips to curve away from the surface just cut and to make the tool less likely to dig in. Both side clearance and front clearance are provided. Great care must be taken to ensure that the tool-bar will remain clear as it is fed in to the hole.

The solid forged-tool shown above is much used, whether for plain boring or internal-thread cutting; there are, however, many useful forms of tool holder, in which a small ground bit is gripped firmly and tightened by a key or wrench, whilst the holder is clamped in the slide rest. Various types of boring tool and holder are shown in the above illustration.

BORON (B). Atomic no. 5 ; atomic wt. 10·82 ; a non-metal, chemically like aluminium and the rare-earth metals; density 2·5; m.p. 2,200 deg. C. There are two varieties of boron, a brown amorphous powder and a hard fused mass. Boron is trivalent and forms a number of hydrides:

B_2H_6, B_4H_{10}, B_5H_9 etc. The oxide B_2O_3 unites with water to form boric acid, H_3BO_3, a mild antiseptic. The sodium salt of this acid, sodium borate (borax) $Na_2B_4O_7.10H_2O$, is a mild antiseptic and is used in the production of hard glass and glazes, and as a flux in soldering.

BOSS. The centre or hub of a wheel or of a fixed-pitch propeller, through which the attachment bolts are passed.

BOUNDARY LAYER, see LAMINAR FLOW.

BOX, see EUCALYPTUS.

BOXED FRAMES, see CASED WINDOW FRAMES.

BOX ANNEALING (Metallurgy). A process of annealing, also known as close annealing (q.v.) which is carried out in a suitable closed metal box or pot to prevent oxidation. The charge is usually heated slowly to a temperature below the transformation range and cooled slowly.

BOX GUTTERS. Lead-covered troughs which are formed between the slopes of two roof surfaces; they may be from 3 to 9 in. deep, according to the length of the gutter and the number of drips.

BOYLE'S LAW. The law stating that the volume of a gas at constant temperature is inversely proportional to the pressure. The law applies exactly only at low pressures.

BRACKETING. The arrangement of wood or metal, often termed cradling, which projects from the wall face and forms a framework or support for plasterwork. On brick walls, or others where a simple key to hold the plaster can be formed, bracketing is not necessary for small cornices.

BRAKE. A means of checking the speed of a vehicle or piece of machinery, usually by the action of friction. On most modern cars, for instance, brakes are provided on all four road wheels, and it is important that the braking effort should be equal on each wheel. The method of controlling brakes differs, but the means of applying the retarding effort is the same. A steel drum is fitted on the hub of the wheel, and curved pieces of metal, termed brake shoes, lined with a friction fabric, are arranged inside to press against the inner surface of the drum. The component parts of a simple type of internal-expanding brake are shown in Fig. 1.

As shown, the torque plate supports an anchorage pin on which the brake shoes pivot. A strong expansion spring keeps the shoes firmly on the pin and holds them together. At a point directly opposite the anchorage pin is an actuating cam mounted on the end of a short spindle which passes through the torque plate. The cam fits between the brake shoes, and as it turns forces the pivoted shoes into contact with the inside of the drum. A lever, secured to the end of the cam spindle, is connected by a system of rods and levers to the brake-operating pedal, or the hand lever beside the driver.

Where hydraulic brakes are used, pipes take the place of rods and levers. The hydraulic system depends upon a "master" cylinder containing a fluid which is acted upon by piston pressure as the brake pedal is depressed. Pipe-lines communicate with each brake, and the fluid pressure is equally

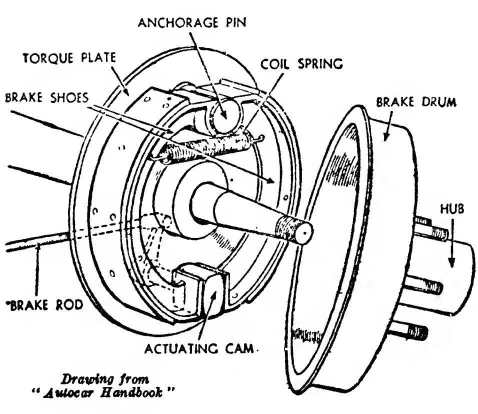
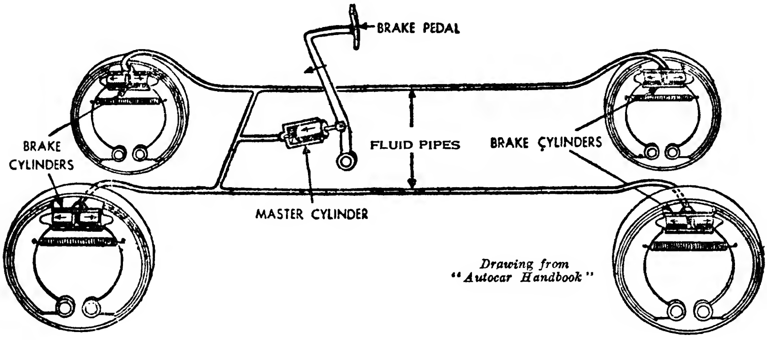


Fig. 1. Internal-expanding brake assembly as fitted to many types of road vehicle.



HYDRAULIC BRAKES INSTALLATION

Fig. 2. Pipes take the place of rods, or cables, and levers in a hydraulically-operated brake system. Fluid pressure in the pipelines forces the brake shoes into contact with the drums, thus applying a retarding effort to the road wheels.

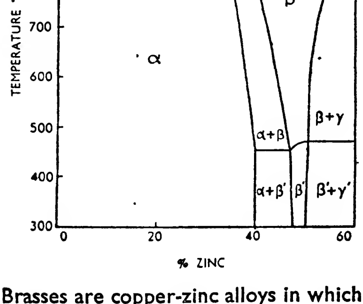
divided between the four points. The braking effort of the shoes is applied by two plungers contained in a cylinder. The pressure of fluid forces the two plungers apart and they in turn push at the brake shoes. The hydraulic brake layout is shown in Fig. 2. To maintain brakes in an efficient condition, periodical inspection and adjustment is advisable. As the friction linings wear down, the position of the brake shoes must be adjusted to reduce the excessive clearance between the lining and the brake drum. Provision for doing this is made on all braking systems, but it is important that the method recommended in the manufacturer's instructions be followed. See also AIR BRAKE.

BRAKE HORSE-POWER. The power developed by an engine as measured by some form of braking—electrical, hydraulic or mechanical—on the crankshaft or propeller shaft. See BENCH TEST and HORSE-POWER.

BRASS. Any copper-zinc alloy containing more than 50 per cent of copper the remainder being all, or mainly, zinc. Brasses are conveniently classified according to their microstructure. A portion of the copper-zinc equilibrium diagram is shown in the diagram.

It will be noticed that the brasses containing up to 39 per cent of zinc consist entirely of the α solid solution, a soft ductile constituent which can be readily cold-worked. The $\alpha + \beta$ brasses contain from 39 to 46·5 per cent of zinc. They are stronger than the α brasses, but, owing to the relative brittleness of the β constituent, cannot be cold-worked.

Alloys which come in this range are suitable for hot-rolling and extrusion processes. The β brasses containing from 46·5 to 49·5 per cent of zinc are



Brasses are copper-zinc alloys in which the two basic metals vary in proportion, copper being predominant.

still less ductile and are used only as casting alloys.

Brasses are commonly described according to their copper : zinc ratio; 60 : 40 is common brass; 70 : 30 is cartridge; 75 : 25 is dipping; 90 : 10 is gilding and so on. Small proportions of elements other than copper and zinc are sometimes added to modify the properties of brass. Thus naval brass contains 62 per cent of copper, 37 per cent of zinc and 1 per cent of tin, the tin considerably increasing the resistance of the brass against corrosion. The addition of 2 per cent of aluminium is even more effective; brass of 76:22:2 composition being used for condenser tubes working in contact with sea water. The presence of 2 to 4 per cent of lead in brass greatly increases the speed at which it may be machined, but since lead reduces the ductility, the presence of more than 0·1 per cent is undesirable in alloys intended for deep drawing. Small proportions of iron, aluminium and manganese produce a considerable improvement in the strength of $\alpha+\beta$ and β brasses. Such alloys are known as high-strength brass or, incorrectly, as manganese bronze.

Recently, cast brasses have found considerable application as substitutes for gunmetal, the two grades most commonly employed containing 70 to 80 per cent and 62 to 70 per cent of copper respectively, the balance in each case being zinc.

BRAUNITE, see MANGANESE.

BRAZING. A method of uniting metals by an alloy, usually brass or spelter, introduced between them in the form of a thin film. It is sometimes loosely referred to as hard soldering, but this term is more correctly applied when silver solder, and not brass is used. The process must be carried out at a red heat and a flux, usually borax, is needed to prevent oxidation of the hot metal surfaces. Heat can be applied in various ways but the process is fundamentally the same. The surfaces to be joined are first cleaned and then fixed, or clamped, by suitable means so that relative movement cannot take place; the brazing wire is placed in position, after which the joint is heated, and the flux applied. Heating continues until the brazing medium melts and unites the surfaces to be joined. One of the most important factors in successful brazing is the meticulous cleaning of the surfaces to be joined. Brazed joints will withstand much more intense heat than soldered joints, and their mechanical strength is much greater. The alloy used to form the metallic film sometimes known as spelter, consists of approximately equal proportions of copper and zinc.

The following is a brief summary of the methods in general use:

TORCH BRAZING. In this system a torch is used as the heating medium. The types of torches in general use are coal-gas and compressed air, oxy-coal-gas, oxy-hydrogen and oxy-acetylene. This is the most frequently used method, and requires least equipment.

FURNACE BRAZING. In this, the work, with the brazing alloy preplaced in the joints, is loaded into a furnace in order to raise the whole of the work to a temperature exceeding the melting point of the brazing alloy, thus automatically effecting a union of the joints.

ELECTRIC-RESISTANCE BRAZING. In this method the sources of heat are the electrodes of the secondary winding of a transformer. The electrodes may be of such materials as copper, copper alloy, stainless steel, nickel-chromium alloy or carbon. The brazing alloy may be preplaced in the joint or added when the work is hot, and heating may be produced either by internal resistance at the joint locality, in the case of high-conductivity electrodes, or by conduction from low-conductivity electrodes.

DIP BRAZING. This is done by immersing the joint locality of the work in a bath of molten brazing alloy on the surface of which is a layer of molten flux.

SALT-BATH BRAZING. The work is prepared as for furnace brazing except

that heating is carried out by immersing the work in a salt bath.

FORGE BRAZING. Similar to torch brazing except that the blacksmith's forge is used as the source of heat.

INDUCTION BRAZING. In this method, the source of heat is a high-frequency coil which surrounds the joint locality of the work.

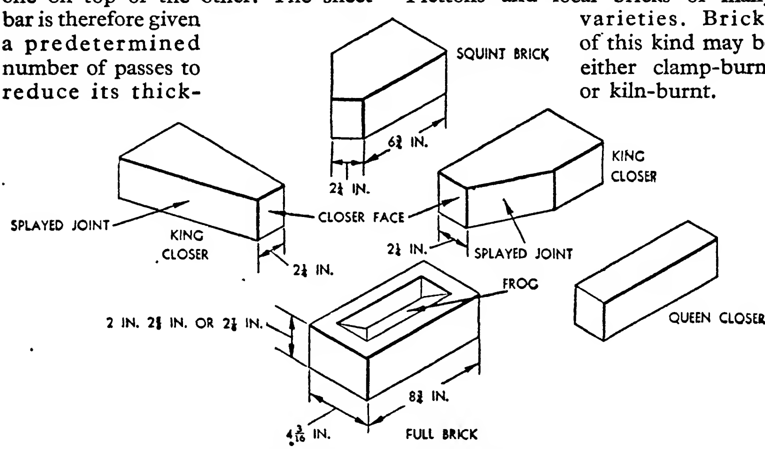
BREAKING-DOWN. In sheet-metal rolling, the process of passing a tinplate sheet or bar through the rolling mill initially to reduce it to matching thickness. As sheets thinner than about 12 B.W.G. cannot be finish-rolled singly except in short lengths, it is necessary to obtain the required length by rolling two pieces, one on top of the other. The sheet bar is therefore given a predetermined number of passes to reduce its thickness and increase its surface area sufficiently for another similar piece to be matched with it. The success of the operation depends upon speed in the initial passes, careful judgment of the size of the pieces to be matched, and accurate screwing.

BREATHER. A device used on electrical transformers for drying the air which is sucked in when the transformer cools.

BRICKS. Constructional units, rectangular in shape, made from special clay and shales, and baked at high temperatures. They are among the most durable of all building materials. There are many kinds of bricks on the market, classified according to their intended use, method of manufacture, and properties. Most types have a frog, or hollow, on one surface, intended to hold the mortar and form a better key for building purposes.

A brief classification of bricks will include: (1) Common bricks, as used for backing; (2) Engineering bricks; (3) Facing bricks; and (4) Special bricks.

COMMON BRICKS include a large selection of machine-pressed wire-cut and hand-made bricks such as Stocks, Flettons and local bricks of many varieties. Bricks of this kind may be either clamp-burnt or kiln-burnt.



COMMON TYPES OF BRICK

Classified according to their use, there are many kinds of brick available, and appropriate names and sizes of some of the more common are shown in this diagram.

ENGINEERING BRICKS are a heavy type of brick, smooth faced and well vitrified. They include Staffordshire blues, Southwater and Accrington types, and are intended for use where strength and damp-resistance are required.

FACING BRICKS comprise hand-made sand-faced reds, purples, greys and multi-coloured bricks made from malm or prepared marl, and used for facing walls.

SPECIAL BRICKS include fire-bricks, common salt-glazed bricks, enamelled

bricks, sand-lime bricks, rubbers, purpose-made bricks and fixing bricks.

For the correct sizes of bricks, reference should be made to the British Standard Specifications, (B.S.S.) No. 657 (1936) *Dimensions of Clay Facing and Backing Bricks*. The standard sizes of bricks may be taken as : $8\frac{3}{4}$ in. × $4\frac{1}{16}$ in. × 2, $2\frac{5}{8}$ or $2\frac{7}{8}$ in. in height, with a toleration of $\frac{3}{16}$ in. in height and width and $\frac{1}{8}$ in. in length. Best pressed bricks and wire-cuts weigh from 7 to 8 lb. each; common stock bricks 6 to 7 lb. each; Fletton bricks 5 to 6 lb. each, and Engineering bricks 9 lb. each. See CLOSER.

BRICKWORK. Bricks bedded in mortar and laid in courses so that they overlap to form a bond; on the setting and hardening of the mortar they become a homogeneous mass. The arrangement of the bricks is such that when a load is placed on any one brick it is transmitted to the other bricks forming the wall. Bricks should be laid frog upward so that the mortar runs naturally into the hollow. The bricklayer's knowledge should extend beyond the various bonds in brickwork; he should be acquainted with the manufacture of the various kinds of brick and be able to classify them to suit any particular purpose. He should understand the composition and suitable mixing of mortars, and have a good knowledge of building construction. A bricklayer's tools are: bevel, bolster, hawk, laying trowel, pins and line, plumb-rule or line, pointing trowel, scrutch, spirit level, steel chisels, steel square and 2 or 3-ft. rule. See BOND, BRICKS and CLOSER.

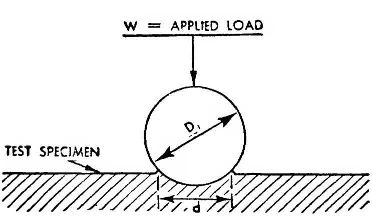


Diagram showing method of calculating the hardness of a metal by means of the Brinell Hardness Test, which employs a hardened steel ball under pressure.

BRIDGE FEED-BACK, see NEGATIVE FEED-BACK.

BRIDLE JOINTS, see JOINTS.

BRIGHT EMITTER. A radio valve whose filament is made of tungsten and glows very brightly at white heat when in use. See RADIO VALVE.

BRIGHTNESS (B). The luminous intensity of a surface in a direction perpendicular to it per unit area of the surface. Alternative names are surface brightness and intrinsic brilliancy.

BRINELL HARDNESS TEST. A system of measuring the hardness of a material by its resistance to deformation by indentation. A hardened steel ball under known load is forced into the specimen for 15 seconds, and the average diameter of the impression measured, as shown, by means of a low-power microscope with a graduated scale. The actual Brinell hardness number (B.H.N.) is given by the formula:

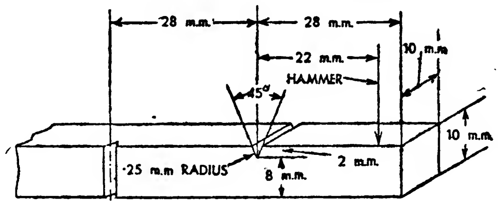
$$\text{B.H.N.} = \frac{\text{Load}}{\text{Area of impression}}$$

$$= \frac{P}{\frac{1}{2}\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

where P = load in kilograms
D = diameter of ball in millimetres
d = diameter of impression in millimetres

In practice it is necessary merely to measure the diameter of the impression and to read off the corresponding Brinell hardness number from a table. With a standard ball of 10 mm. dia., the load for steel is 3,000 kg. When other sizes of ball are used the load is varied in accordance with the relation $\frac{P}{D^2}$ = Constant. The values of this constant for common materials are steel and cast-iron, 30;

copper and aluminium alloys, 10; copper and aluminium, 5; and lead, tin and their alloys, 1. Thus, using a 10 mm. diameter ball on copper alloys, the load will be 1000 kilograms, since in this case $\frac{P}{D^2}=10$.



In what is known as the notched-bar test, standard Izod test pieces such as this are sometimes used. They are gripped in a vice and fractured by a blow from a falling pendulum weight.

The standard ball diameters are 1, 2, 5 and 10 mm. The Brinell hardness test is extremely useful in the routine examination of metallic materials. With hard materials, however, errors result from deformation of the ball, and hardness numbers are not comparative. The Vickers Diamond pyramid hardness tester was designed to overcome these difficulties. In another type of machine the load is applied by oil pressure with the aid of a hand pump. See NOTCHED-BAR TESTING.

BRITISH GUM, see DEXTRINE.

BRITISH STANDARDS INSTITUTION. The national standardizing organization for Great Britain, founded in 1901. It is an independent body, maintained by industry with Government support, and exists to prepare standards of performance, quality or dimension, the chief aims being to eliminate redundant qualities and sizes and provide an equitable basis for tendering. The work is divided into four main classes, engineering, chemical, building and textile, and upwards of 1,400 standards have already been issued. The original title of the organization was the British Engineering Standards Association (B.E.S.A.).

The underlying principles covering the preparation of British Standard Specifications are: (1) that they shall be in accordance with the needs of industry and fulfil a generally recognized want; (2) that the community interest of producer and consumer shall be maintained throughout the work; (3) that periodical review and revision shall be undertaken to prevent crystallization and keep the work abreast of progress; and (4) that there shall be no coercion whatever by one section of the community over another section, standardization being arrived at by general consent. Specifications laid down by the British Standards Institution are given a B.S.S. number.

BRITISH THERMAL UNIT (B.Th.U.). The amount of heat required to raise the temperature of 1 lb. of water 1 deg. F. It is often defined as the amount of heat required to raise 1 lb. of water from 60 to 61 deg. F. One B.Th.U. is equivalent to 252 small calories or 0·252 great calories. It is also equivalent to ·000001 therm.

BRITTLENESS. The susceptibility of a notched specimen of material to fracture under impact or bending stress. A notch in a piece of metal acts as a "stress-raiser," owing to the local concentration of stress at the root of the notch. Hence a notched specimen will fail under impact or bending loads much lower than those required to fracture the same specimen without the notch. Notched-bar tests are commonly used in assessing the properties of materials. Several machines are available, the Izod being commonly used. The specimen, in the form of a notched bar of standard dimensions, shown in above diagram, is gripped in a vice and fractured by a pendulum weight. The energy (in foot-pounds) absorbed in fracturing the specimen, indicated by the reduction in the upward swing of the pendulum, is read-off on a circular scale.

The real nature of notch sensitivity is not understood, but impact tests are

extremely valuable indications of the toughness and shock-resistance of a material, and of its ability to withstand stress concentration at a change in section. See NOTCHED-BAR TESTING.

BROACHING. The altering of the cross-section, or internal surface finish of a hole already roughly formed in a workpiece by pushing, or drawing, through it a tapered cutting-tool provided with a number of ground teeth. The teeth are so formed that they increase in size from the entering end of the tool to the finishing end. *Push* broaching consists of forcing a comparatively short tool through the hole, employing for the purpose a press operated by mechanical or hydraulic means; small examples may be hand-operated.

Pull broaching machines usually employ much longer tools, the reason for drawing instead of pushing them through the workpiece being that the action of pulling obviates the risk of bending which is present in push-broaching. *Internal* broaching can be used for a variety of purposes, e.g. the enlarging of square or round holes and keyways, the formation of splines or splineshafts and the cutting of internal gears. It can also be used in all these applications for the improvement of the surface finish. *External* broaching is used to impart the desired external profile to the cross-section of a workpiece (e.g. in shock-absorber wings); with a hollow broach, therefore, as necessitated in this case, either the broach may be drawn over the workpiece or the workpiece may be drawn through the broach. Broaching affords a quick and simple means of effecting such changes in section as those mentioned, particularly when the required limits of accuracy are not high. A travel, or cut, up to 6 ft. with a broaching tool is practicable.

BROADCASTING. The transmission of speech and music to be received by the public. The term is used in connexion with daily entertainment, news bulletins, weather reports etc.

In 1919, experiments were conducted by the Marconi Company at Chelmsford, Essex, and in 1920, permission was granted to establish the first transmitter for entertainment and educational purposes. A station was accordingly erected at Writtle, near Chelmsford and, at first, only a short programme was given once a week, but later, the transmitter operated more frequently and for longer hours.

In May, 1922, the Marconi Company began to radiate programmes of speech and music from a transmitter at Marconi House, London, and thus was born the famous 2LO. It soon became obvious that broadcasting had a great future and a conference was held between the Postmaster General and representatives of firms manufacturing electrical equipment.

Formation of B.B.C.

As a result of this meeting, six of the leading manufacturers formed the British Broadcasting Company which officially came into being on October 18th, 1922, and guaranteed to establish and maintain a broadcast service for a period of two years. Stations were to be provided at London, Birmingham, Newcastle, Cardiff, Manchester, Glasgow, Aberdeen and Bournemouth.

The B.B.C. received in return a licence giving them exclusive right to broadcast entertainment in Great Britain. Broadcast-receiving licences were issued by the Post Office at a cost of ten shillings each and it was made compulsory for owners of receiving apparatus to obtain one. At that time half the revenue from such licences went to the B.B.C. who also received a royalty on all broadcast-receiving apparatus sold. On November 18th, 1922, broadcasting began from the London, Manchester and Birmingham stations, and the remaining stations came into operation during the following twelve months.

When the B.B.C. licence expired in 1924 it was renewed for another two years. In April, 1925, a high-power long-wave transmitter was opened at Daventry using the call-sign 5XX and, in the same year, the London transmitter at Marconi House was dis-

mantled, being replaced by more powerful apparatus installed in Oxford Street.

In 1926, upon the expiry of the renewed licence the Government took control of the B.B.C. which then became the British Broadcasting Corporation with a Royal Charter.

Experiments still continued. In August, 1927, an experimental transmitter was erected at Daventry and allotted the call-sign 5GB and, in the following November, a short-wave station using the call-sign 5SW was opened at Chelmsford.

The next step in development occurred in the year 1929 with the commencement of a regional scheme which was to provide alternative programmes in each service area, a common National programme on one wavelength and a local, or Regional, programme on another. On October 15th of that year, Brookmans Park (Herts), the first of a series of high-power twin-wave stations, came into service superseding the existing London transmitter. Other similar stations followed, covering the whole of Great Britain, and an additional high-power long-wave station radiating the National Programme was set up at Droitwich to replace the older transmitter at Daventry.

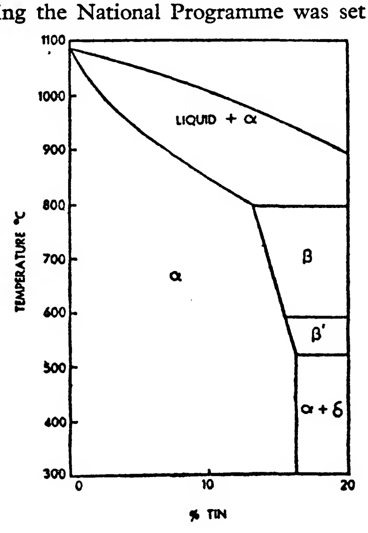
The original London studios and offices were at Marconi House and Magnet House respectively, but it soon became necessary to look for new and larger premises where they might be in the same building. In March, 1923, the B.B.C. established themselves at Savoy Hill where they stayed for nine years, moving in 1932 to their now well-known headquarters at Broadcasting House in Portland Place, London.

With the outbreak of war in September, 1939, the B.B.C. stations became anonymous. A special European service was inaugurated and many additions were made to the Empire short-wave stations so that the voice of Britain could reach the ends of the earth.

In Great Britain, broadcasting is the monopoly of the B.B.C., but in some countries it is largely in the hands of commercial organizations. In the U.S.A. and certain other countries, the broadcasting undertakings, operating under licence from the appropriate authority, radiate programmes sponsored and paid for as advertising by business concerns. On the whole, the system is run on lines not unlike those of a daily newspaper; news bulletins, weather forecasts and items of general or topical interest are featured, but advertising forms the largest part of the day's programmes. Revenue is derived, not from part of a receiving licence fee, but from those who sponsor the programmes, time "on the air" being sold rather like space in the press.

BROMINE (Br). Atomic no. 35; atomic wt. 79·916; a dark-red liquid; density 3·188, m.p. −7·3 deg. C., b.p. 58·8 deg. C. It resembles chlorine and iodine in its chemical properties and is usually monovalent.

BRONZE. Any alloy of copper and tin in which the proportion of copper is large compared with that of the tin. Commercial bronzes generally contain 5 to 20 per cent of tin. In addition a minute proportion of phosphorus, or alternatively a small percentage of



Bronze consists of an alloy of copper and tin, the former being present in far greater proportion than the latter.

zinc, may be added to improve the foundry characteristics of the particular alloy. Phosphorus in larger amounts, say 0·1 to 1·5 per cent, exerts a considerable hardening effect, the alloy then being known as phosphor bronze (q.v.). The term bronze is also used to describe alloys in which the tin has been wholly replaced by another element. Thus aluminium bronze contains copper and aluminium, but no tin.

A portion of the copper-tin equilibrium diagram is shown in the illustration appearing on the previous page. It will be seen that alloys containing up to 16 per cent of tin should consist entirely of the α solid solution, a soft ductile constituent. In cast alloys, this condition is rarely obtained. On solidification, the crystals first deposited are rich in copper, the residual liquid therefore becoming progressively richer in tin. When the proportion of tin in the liquid exceeds 16 per cent, a second constituent, the δ phase, appears. This phase is exceedingly hard and brittle and confers good bearing properties on the bronze. Alloys containing as little as 8 per cent of tin often show, in the cast state, appreciable quantities of the δ phase. On hot rolling the crystals are broken-up, the composition of the alloy becomes uniform throughout and the δ phase disappears.

The best-known of all bronzes is Admiralty Gunmetal which contains 88 per cent of copper, 10 per cent of tin and 2 per cent of zinc. The minimum tensile strength of this alloy is 16 tons per sq. in. with 8 per cent elongation. This alloy is useful for duties where considerable resistance against corrosion is essential, as for example, in centrifugal pumps dealing with sea water. It also possesses good properties as a bearing material which are still further improved by incorporating several per cent of lead in the alloy.

BRONZE (Painting). A general name for powder-like materials consisting of alloys of copper and aluminium cut into micro-scopic flakes. The range of colours possible by admixture of the metals is further extended by staining the surfaces of the flakes with dyes soluble in alcohol. This makes it possible to obtain rich greens, blues, purples and reds. Bronze may be mixed with various media to produce paints which can be applied with a brush and which dry with a metallic lustre. These are also used for dusting upon partially dry japanners' gold-size in the decorative treatment of textured surfaces and ornament in relief. A bronze applied in a dry form by dusting must be protected by a coating of lacquer to prevent oxidation of the copper content. Bleached shellac dissolved in alcohol was formerly used for this purpose, but in modern practice this has been replaced by the use of transparent cellulose lacquer.

BRONZE GREEN, see GREENS.

BRONZE WELDING. The process of joining various commercial metals and alloys by melting on to the heated surfaces and edges a bronze filler-rod composed basically of 60/40 copper-zinc alloy, free from impurities and incorporating a controlled percentage of silicon. Bronze welding is a heterogeneous form of joint made by direct flame-application, involving manipulative control of the heated area and the molten bronze metal. By this process dissimilar metals may be joined, provided that the fusion temperature of the parent metal is in excess of 800 deg. C. The tensile strength of the deposited bronze filler-metal is 28 tons per sq. in., but the strength of the joint depends upon the adhesive power of the alloy when bonded to the surfaces of the parent metal; this strength may vary from 8 tons per sq. in. to 26 tons per sq. in., according to the composition of the metals joined, the preparation and cleanliness of the metal surfaces, and the control of applied heat.

Some authorities contend that the strength of a bronze-welded joint is achieved by the process of surface alloying, others by contact forces, or, alternatively, by surface tension. There is evidence to support each of these theories which seem to depend

on the class of metal under examination. Correctly made, a bronze-welded joint will provide a strength comparable with one made by other welding processes. The bronze-welding process may be carried out with any type of heating flame which is capable of heating the parent metal to 800 deg. C. (red heat), and simultaneously melting the bronze filler rod. Such flames are oxy-acetylene, oxy-coal gas, oxy-hydrogen, coal gas and air etc. The oxy-acetylene flame has the highest concentration and intensity in localized areas; also it is in most general use and permits variable adjustment and manipulative procedure according to requirements. For these reasons this flame is generally recommended for bronze welding.

BRONZING. The production of a bronze metallic effect on a printed sheet. The area or design to be so treated is printed in a special drying medium or a drying ink mixed to approximate to the final result required. This is then dusted over with the metallic powder or bronze, which adheres to the printing ink and becomes firmly fixed as the ink dries. The quality of the finished result is influenced by the kind of paper used, the regularity of ink supply, the uniform condition of the ink when the bronze is applied, and the even application of the powder. These and other factors affect the final metallic lustre. Formerly the powder was applied by hand with a wad of cotton wool.

Numerous types of container-pads were also evolved which permitted a ready supply of bronze by simple trigger control. Modern application is by machines of flat or cylindrical type. The former can accommodate paper, card and metal sheets, and uses oscillating bronzing, dusting and burnishing bands; the cylindrical type uses fabric rollers, sometimes in combination with burnishing pads. These machines can be synchronized with some printing machines, and the complete printing, bronzing and dusting operations may be carried out without any hand operations. Despite the most careful precautions the atmosphere of the bronzing room becomes charged with the fine metallic powder, so that at best, bronzing is an objectionable job.

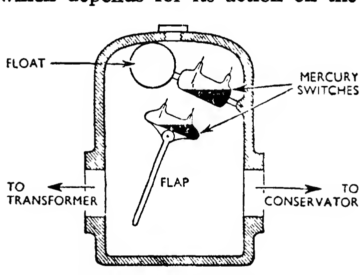
BRUNSWICK BLACK. A cheap form of black varnish, for use upon internal ironwork, composed of refined tar reinforced with resins. It always remains readily soluble in turpentine, but will resist the action of acids. To a limited extent it is used as a stop-out when embossing glass with hydrofluoric acid.

BRUNSWICK BLUE, see PRUSSIAN BLUE.

BRUSH. (Elec. Engineering). A block, usually of carbon, enployed for rubbing-contacts in electrical machines and other apparatus, for example, on commutators and slip-rings.

BRUSH DISCHARGE. A visible electrical discharge somewhat resembling a feather-duster in appearance. It is usually accompanied by a crackling noise.

BUCHHOLZ RELAY. A protective device for electrical transformers which depends for its action on the



Buchholz relay as inserted in the pipe joining a transformer to its conservator. Normally the relay chamber is full of oil. In the event of a fault in the transformer, the relay acts as described in the text, so that the mercury switches are closed.

gas which is given off when a fault occurs. Severe faults cause rapid evolution of gas which deflects a vane and causes the transformer to be switched off, whereas gas which is liberated slowly is trapped and

operates a float switch to give an alarm. The diagram on the previous page shows the principle of the relay.

BUCKING, see BOOSTER.

BUFFETING (Aero. Engineering). A vibration caused when disturbed or turbulent air flows off one part of an aircraft and strikes another part. Possibly the most common example of buffeting occurs in some low-wing monoplanes. When flying just above stalling speed the wing roots may be partly stalled and the turbulent air from them strikes the tail plane. This is indirectly advantageous as it provides the pilot with an unmistakable warning of the approach of the stall.

BUILDING. The art of constructing and raising an edifice. So far as the erection of houses is concerned, it is a combination of activities undertaken and supervised by a practical builder. Owing to the introduction, however, of steel and reinforced concrete, and of services such as central heating, ventilation, air-conditioning, lighting, lifts and acoustical requirements, a much more complicated industry has developed, requiring specialists in each of the various branches.

In modern building, specialists are engaged for excavating, pile-driving, foundation concreting, steel-work, brickwork, stonework, fireproof floors, plasterwork and joinery, in addition to those required for the services mentioned, and for decoration.

As regards the carcase, i.e. the structure of a house or block of flats, there are two main forms of construction, block construction and skeleton-frame construction. In block construction the walls are built up block by block and these support the roof, floors and all superimposed loads. In skeleton-frame construction, a framework is first erected to support the walls and all loads normally taken by them. Skeleton-framing is further divided into steel framing and re-inforced-concrete framing. The former has many advantages, chief of which is the fact that the fabricated steel members are delivered to the site ready for assembly and can be rapidly welded or riveted together. Reinforced concrete members have to be framed on the spot, and the material must harden or set before the process of erection can continue. Reinforced concrete framing is *monolithic*. The steel frame consists of vertical members termed stanchions, or pillars, which transmit the loads to the foundations, while the horizontal members are intended to tie the vertical members, and to carry the loads of the walls, floors, and roof. Constructional processes are explained under their various headings. See BOND, BRICKS and BRICKWORK.

BUILT-UP ROOF COVERINGS. Materials adapted to flat roofs of large area where metal coverings are unsuitable. They comprise a series of layers, or plies, which can be laid on timber framing or on concrete and hollow-block slabs. When laid on timber, the framework should be close-boarded and covered with a layer of thick paper or felt, the joints of the paper or felt being lapped. Two layers of tarred felt, properly lapped, are then laid over the area and coated with tar and pitch, into which, whilst hot, is embedded sand or crushed gravel.

If the roof is intended for use as a promenade, cement roofing tiles or Paropa tiles can be laid on the tarred surface and jointed in mastic. When laid on concrete slabs, a coating of pitch is poured over the concrete surface and two layers of tarred felt are then laid so that the joint edges of the felt are lapped. The building-up is completed by a final coating of tar and pitch, or a two-ply layer of mastic asphalt. If desired, the roof may be finished with a topping of cement or Paropa tiles.

BUOYANCY. The force acting upon and supporting any mass or object floating in a gas or a liquid. This force is conventionally regarded as acting upwards, i.e. in an opposite direction to the force of gravity, and will be equal and complementary to the gravitational attraction (weight) when the mass is in equilibrium.

BURDEN (Elec. Engineering). The load imposed upon the secondary of an instrument transformer by instru-

ments or relays which are supplied by it. A burden is customarily expressed in volt-amperes, that is, the product of the voltage across it and the current through it; 15 volt-amps. is a common value. See INSTRUMENT TRANSFORMER.

BUS-BAR. An electrical conductor from or to which a number of independent connexions are taken. A common example is provided by the heavy copper bars in a sub-station to which the supply is connected and from which feeders are tapped-off as required.

BUSHING. An insulator used to permit the passage of an electric wire or cable through a partition such as the side or top of a transformer tank. For high voltages, condenser bushings are used. These consist of alternate layers of insulation and metal foil wound round a central conductor. The lengths and diameters of the foil layers are so arranged that the potential gradients through and along the outside surface of the bushing are uniform. This makes for electrical strength. See POTENTIAL GRADIENT.

BUTADIENE. A colourless gas produced in the cracking of petroleum; also known as *Divinyl*. When heated with sodium and certain other substances it polymerizes, forming a rubber-like substance, and is used in the preparation of some types of artificial rubber. It has the constitution $CH_2:CH.CH:CH_2$.

BUTT JOINTS, see JOINTS.

BUTTONS, see JOINTS.

BUZZER. An electro-mechanical device working on the same principle as an electric bell. There is no hammer or gong, however, the buzzing sound being produced solely by the vibrating armature. See ELECTRIC BELL.

CABLE (Elec. Engineering). An electric cable for power distribution consists of a conductor, or a set of conductors, insulated throughout its length and usually enclosed in a protective sheath of metal. The cable may be buried in the ground, laid on racks, or slung from an overhead wire.

The conductors are almost invariably made from copper, stranded for flexibility, the strands being twisted or laid-up together. The number of strands is such that they, together, approximate to a circle in section, and there may be 3, 7, 19, 37, 61 etc. of these strands in standard sections.

Insulation may be rubber, paper, bitumen, or cambric, but for power cables the usual material is paper. This paper may be made from manilla, or from wood pulp, the latter being the more common; it is used in the form of a tape about five thousandths of an inch thick.

In making a multi-core cable, each core, stranded as explained above, is wrapped with paper tape until the required thickness has been built-up. The required number of cores, usually three, are then laid up, or twisted, together with wormings, or fillers, of jute or paper to fill the spaces between the cores and to give a compact circular section. At the same time another layer of paper tape is built-up round all the cores to form the belt.

After drying, the cable is impregnated and is then ready for the application of the sheath. The primary purpose of the sheath is to prevent the paper from absorbing water from the air, but it also gives sufficient mechanical protection for many situations. This sheath, which is made of lead alloy, is applied by means of a continuous extrusion process.

Extra mechanical protection is afforded by one or two layers of steel wire or tape and a layer, or serving, of jute or hessian to prevent damage to the lead by the armour.

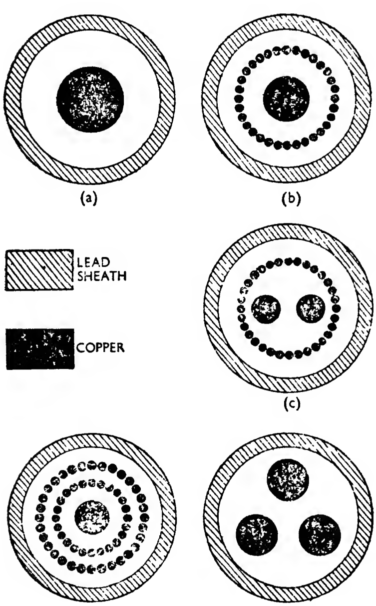
The completed cable is often described by means of a sequence of letters, for example, PILSWA which is interpreted to mean "Paper insulated, lead covered, steel wire armoured". Some cross-sections of cables used for power work are shown

in the accompanying illustration, while the caption gives the names of common types.

Armoured cables are usually laid direct in the ground with the addition, sometimes, of a row of boards or tiles to warn the man with a pick that he is approaching something vulnerable.

In busy places, cables are drawn into ducts consisting of earthenware pipes with manholes at regular intervals, or are laid in racks in a tunnel. This is an expensive method, but it has the advantage that the cable can be laid or withdrawn without disturbance of the road suface.

As the voltages used in transmission increase, the normal cable begins to give trouble. One of the limiting factors in cable design is the dielectric stress. If this exceeds a safe value, the cable breaks down. Unfortunately the stress is not uniform. In a single-core cable, the stress at the surface of the conductor is very much greater than it is at the outside surface under the lead sheath, and in the case of three-core cables there is the additional complication that the stress is not purely radial, but has a component, along the surface of the tapes, which is not so easily resisted. This means that while the outside layers of paper are quite comfortably able to withstand the stress, those near the conductor may break down.



Cable sections illustrated here are: single-core (a), concentric (b), twin-concentric (c), triple-concentric (d) and three-core (e). The first and last are the most common, but (d) is used in high-voltage alternators. Details of insulation are intentionally omitted.

The first problem may be overcome to some extent by dielectric grading. In the ideal case, the permittivity (q.v.) of the paper should be inversely proportional to the radius at which it is situated, and if this were so the stress would be uniform. It is not practicable, however, to use more than two or three different papers for this purpose.

The use of intersheaths is another possibility. In this system one or more conducting layers, called intersheaths, are built into the insulation. By applying suitable potentials to these it is possible to make the stress at the outside circumference of each the same as the stress at the conductor and in this way the insulating material is more uniformly stressed.

Although this scheme has not found favour for cable work, a modification of it has been successfully applied in the manufacture of alternators to generate at 33kV.

The other problem to be solved, that of non-radial stress, may be overcome by surrounding each core with a conducting layer or screen, as in the H-type cable, or by a separate lead sheath enclosed within the main sheath (S.L. Type).

In either case the result is the same; each core behaves electrically as a single-core cable so that the stress remains radial.

Another cause of trouble is the formation of voids. When the cable warms up the lead sheath expands, but it does not contract so much when the cable cools again. This leads to empty spaces within the sheath which

are not as strong electrically as the impregnated paper.

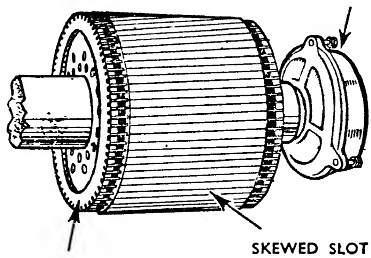
Intensive research on these problems has lead to the invention of a number of new types of cable, especially suited to high-voltage working. In one type the lead-sheathed cable is enclosed in an iron pipe filled with gas under pressure. The object of this is to force the lead back into place when the cable cools and so prevent void formation.

Another type uses a hollow conductor in which oil is kept under pressure. In the event of a void being formed it is filled up with oil and no trouble occurs. Yet another design uses high-pressure gas as a filling medium.

Mention should be made of heating problems. Heat is produced in a cable both by copper loss and by dielectric loss, and if the insulation is not to carbonize, this heat must be dissipated at a reasonable temperature as fast as it is produced. Good insulators are also bad conductors of heat so that the temperature inside the cable is greater than that outside. Moreover, dielectric losses increase with temperature and also lead to an increase in temperature.

In certain circumstances, an unstable condition may result, in which the temperature continues to rise until the cable breaks down. It thus appears that the current which a cable may carry with safety is limited by temperature rise, which itself depends not only on the design of the cable but also on the manner in which it is laid and on the distance between adjacent cables.

CADMIUM (Cd). Atomic no. 48; atomic wt. 112·41; a soft, bluish metal obtained in the smelting of zinc ores; it is more volatile than zinc, and may be recovered from zinc furnaces in which zinc is reduced; density 8·64; m.p. 321 deg. C.; b.p. 767 deg. C. It is used in thin layers as a protective coating on steel, and also as an alloy of copper. Cadmium is also alloyed with aluminium, and is a component of various anti-friction alloys and solders. With tin and bismuth it forms some very fusible alloys. It is a divalent element, forming compounds



Squirrel-cage rotors in electric motors, are self-contained, and require neither slip-rings nor commutators.

such as cadmium oxide, CdO, and cadmium sulphate, $CdSO_4$. The cadmium cell is an electric cell with a cadmium-mercury amalgam cathode and a mercury anode in a saturated solution of cadmium sulphate. Cadmium sulphide, CdS, is an orange or yellow powder insoluble in water; it is used in the ceramic and rubber industries and as a pigment for colouring soap.

CADMIUM PLATING. An electroplating process which gives excellent protection to iron and steel. There has been much discussion on the relative plating merits of zinc and cadmium, and although the salt-spray test indicates that cadmium is superior to zinc, it is difficult to decide which of the two metals is the more suitable under ordinary conditions of exposure.

CAESIUM (Cs). Atomic no. 55; atomic wt., 132·91. A whitish, soft metal similar in many ways to sodium and potassium; density, 1·90; m.p. 28·45 deg. C.; b.p., 670 deg. C. Caesium compounds are used in some photo-electric cells because, when exposed to light, the compounds emit electrons. Caesium is monovalent and forms a chloride $CsCl$.

CAGE ROTOR. A type of rotor, used in squirrel-cage electric motors, which requires no external connexions.

It frequently consists of a number of copper bars parallel to the axis of the machine, or slightly skewed, brazed

into rings at each end. The arrangement is shown in the diagram. The cage may also be die-cast in one piece. See INDUCTION MOTOR.

CAIRNGORM, see QUARTZ.

CALCIUM (Ca). Atomic no., 20; atomic wt., 40·08; a soft, silvery metal that oxidizes on exposure to air; density 1·545; m.p., 810 deg. C.; b.p., 1175 deg. C. It is one of the most abundant elements, limestone and chalk being calcium carbonate, $CaCO_3$ while dolomite is a mixture or compound of calcium carbonate and magnesium carbonate. Calcium is divalent, and forms many important compounds.

Calcium Carbide, CaC_2, is formed by heating lime and coke to a high temperature in an electric furnace; when the grey carbide is brought into contact with water it forms the gas acetylene, used in acetylene lamps.

Calcium Carbonate is used in medicines, but its principal use is in the manufacture of lime, CaO, for fertilizing the land.

Calcium Chloride, $CaCl_2$, is used in refrigerating plants.

Calcium Gluconate $[CH_2OH.(CHOH)_4{\cdot}COO]_2Ca,H_2O$, is a valuable drug in cases of malnutrition.

Quicklime, CaO, and *Slaked Lime,* $Ca(OH)_2$ are used for many purposes.

Calcium Sulphate, $CaSO_4$, occurs naturally as anhydrite and gypsum, the latter containing water in combination.

Calcium Superphosphate, $CaH_4(PO_4)_2$, is largely used as a fertilizer.

Calcium Fluoride, fluorspar, CaF_2, is a colourless or blue mineral, used as a flux in the steel industry and the glass industry.

Calcium produces various materials used by the painter. Combined with oxygen it is known as quicklime, and is obtained by burning limestone (carbonate of lime). Freshly burned lime added to clean water produces the material used for limewashing.

In combination with carbonic acid, hydrogen and oxygen, calcium is the natural mineral chalk which, when prepared by grinding, levigating, i.e. grinding to powder in water, and drying, is the pigment *whiting*; the finer qualities are known as *Paris white.* It is the base pigment for most glue-bound distempers, and in combination with linseed oil forms ordinary glazier's putty.

Calcium, sulphuric acid, hydrogen and oxygen form the mineral gypsum of which selected portions are used as the marble alabaster. When this mineral is baked, to drive out the crystalline water content, and pulverized, it is the material *plaster of Paris,* (q.v.) the peculiar properties of which are employed in repairing breaks and defects in plastered surfaces.

All these materials are slightly alkaline; if they become damp with water they may react with the acid content of the oils used in painting and destroy the film.

CALENDERING. A finishing treatment given to paper by passing it through a vertical bank of alternate chilled-iron and paper rolls under heavy pressure. The effect is to produce a smooth burnished surface and a more compact substance. The treatment is usually carried out in the papermaking machine and is less thorough than super-calendering. For certain examples of printing, calendered paper is more economical than imitation art or art paper.

CALOMEL, see MERCURY.

CALORIE. A unit of heat in the c.g.s., or metric, system; it is the amount of heat necessary to raise the temperature of 1 gram of water at 15 deg. C. by 1 deg. C. It is equivalent to 4·2 joules or $4{\cdot}18 \times 10$ ergs. The great Calorie, Cal., is 1000 calories; 1 British Thermal Unit (B.Th.U.) is 252 gm. calories; 1 British Thermal Unit per lb. is 1·8 calories per gram. Calories are used mainly to denote the heat value of foodstuffs and fuels.

The heat given out by one gram of a carbohydrate such as sugar, when digested and oxidized, is 4100 calories or 4·1 great calories (4·1 Cal.). Fats have a calorific value of about 9·3 Cal. Proteins are considered to have a calorific value of about 4·1 Cal. The calorific value of fuels in Great

Britain is usually expressed in lb. calories per pound of fuel, or in British Thermal Units; the calorific value of gaseous fuel is usually expressed in

Fuel	lb.calories per lb.	B.Th.U. per lb.
Wood	3,300	5,950
Steam Coal	8,000	14,400
Petroleum	10,400	18,700
Petrol	11,100	20,000

therms per cubic foot; 1 therm is 100,000 B.Th.U. The above table shows the relation between pound calories per pound of fuel and British Thermal Units per pound.

CAM. A device for converting rotary motion into reciprocating movement, and transmitting it to any piece of mechanism. As a rule it consists either of a plate or a cylinder, which is known as the "driver" since it imparts the necessary movement, and of a spindle or "follower", which receives the movement from the driver.

Cams involving plates are usually arranged so that either the plate itself is shaped to the desired outline, or else carries a suitably shaped groove or track to accomplish the same purpose. In this category heart-shaped cams (as on the household sewing machine spool-winder) or volute cams are very common.

In cylindrical cams the curved face carries the groove, which is thus no longer in one plane, and the follower is therefore constrained to move to and fro in a direction parallel with the longitudinal axis of the cylinder.

Cams can be arranged so that the follower is accelerated at a uniform rate, and decelerated similarly; in between these events a "dwell" can be arranged so that no movement at all is transmitted to the follower, which is thus held stationary at any desired position.

Cams are much used in automatic lathes, for governing the sequence of operations in the production of small components (e.g. turning, screw-cutting, parting-off etc.) in printing machines (e.g. for the feeding and delivery of the sheets of paper in the presses) and in textile machines.

Cams are also used to operate valve mechanism and electrical contacts in ignition systems on internal-combustion engines. In valve operation the tappet or follower is held in contact with the cam circumference by spring pressure so as to obtain movement as the lobe, or projecting part of the cam, makes contact with it.

In magnetos a wide ring having a projection on its inner circumference is used. The ring is stationary and a

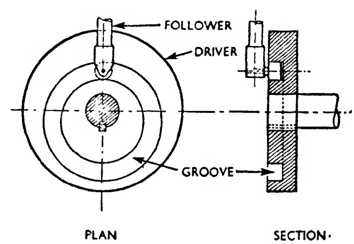
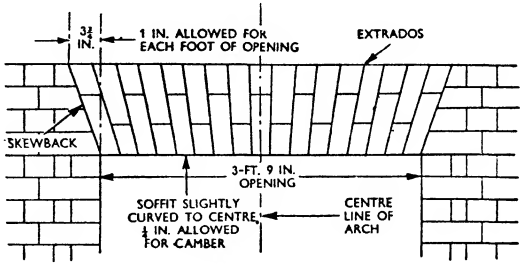


Plate cam, such as that shown here, has a plate or cylinder, termed the "driver", shaped to the outline necessary for providing the desired reciprocating movement, or a suitable groove. The "driver" operates in conjunction with what is known as a "follower" to receive the movement.

rotating lever, moving over its surface, produces the movement. In polar-inductor magnetos the cam rotates.

Cams having two or more lobes are frequently used on ignition apparatus, also on printing machinery, machine tools, automatic machines etc.

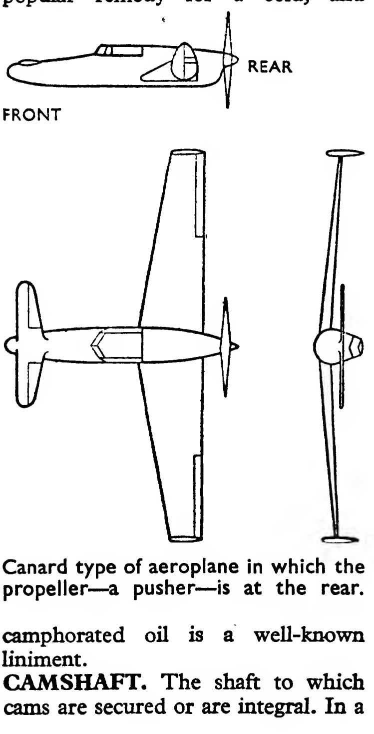
CAMBERED ARCH. A flat or straight-line arch of which the extrados or top surface is straight and the soffit slightly curved upwards. The curve or camber is introduced to prevent a sagging appearance. The amount of camber may be obtained by allowing ⅛in. rise for each foot of span. The skewback, or surface of abutment, should incline at an angle of not less than 60 deg. to the horizontal, so that the arch conforms to an easy wedge and contains within its



Dimensions of a cambered arch, shown here, are calculated as explained fully in the accompanying text.

perimeter an invisible segment of a circle. A good rule for obtaining the angle for the skewback is to allow 1 in. fall back for every foot of opening when the face of the arch is 1 ft. wide.

CAMPHOR ($C_{10}H_{16}O$). A white, crystalline solid obtained from the wood of the camphor tree (Formosa) and certain other plants. It is also manufactured artificially from pinene. Camphor easily sublimes at ordinary temperatures, and melts at 178 to 179 deg. C. It is used in the manufacture of celluloid, explosives and medicine. A few drops of spirit of camphor on a lump of sugar make a popular remedy for a cold, and



Canard type of aeroplane in which the propeller—a pusher—is at the rear.

camphorated oil is a well-known liniment.

CAMSHAFT. The shaft to which cams are secured or are integral. In a four-stroke internal-combustion engine the camshaft makes one revolution to two of the crankshaft and is driven from the engine crankshaft by a system of gear-wheels or chains. The camshaft may be utilized to drive other engine components, such as the ignition distributor or magneto, and the water and oil pumps.

CANARD. A type of aeroplane in which longitudinal stability is provided by an auxiliary wing, placed forward of the main plane, instead of by the tailplane as in conventional types. Certain advantages such as the elimination of spinning were claimed for this type of aircraft in the early days of flying.

Three views of a typical canard arrangement are shown in the accompanying illustration, from which it will be seen that the propeller—of the pusher variety—is at the rear of the aeroplane.

CANARY WOOD. A light hardwood found in the U.S.A., used for fixed joinery, carving etc. Several other species are imported to Britain with canary wood, under the name of American whitewood; these include basswood, magnolia, and cottonwood. Canary wood is more variable in colour, however, having shades of yellow, green and brown in the same piece. See TIMBER.

CANDLE-POWER. The luminous intensity, which means roughly the ability to illuminate, of a source of light, expressed in standard candles. The candle-power of a gas-filled lamp is about twice its rating in watts. See MEAN-SPHERICAL CANDLE-POWER.

CAN-MAKING. The essential operations in can-making are (1)

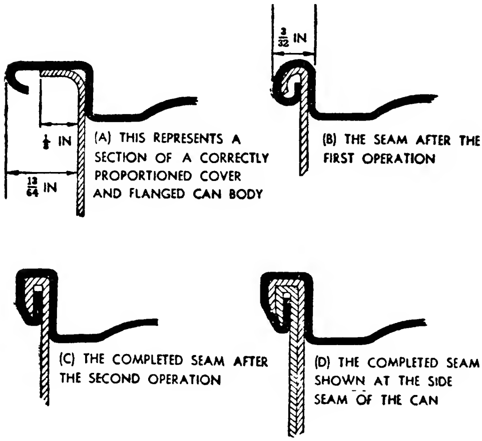
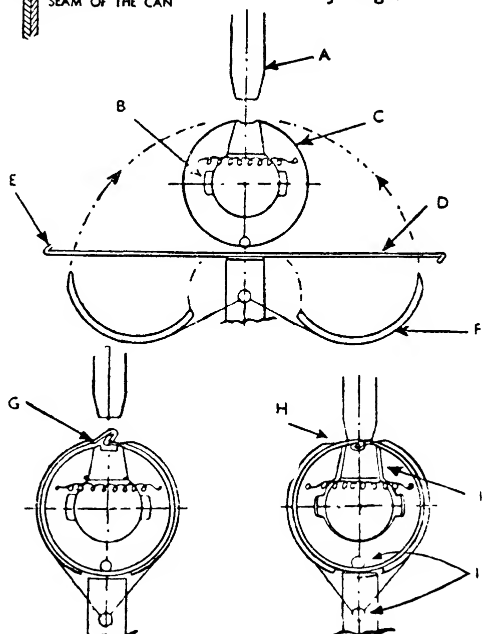


Fig. 1. (Left). Diagram showing successive stages in the double-end flanging process widely used in the can-making industry.

Fig. 3. (Below). Main components comprising a multiple-head double-seaming machine: *A* hammer; *B* tapered plungers for expanding former; *C* former; *D* body blank; *E* edge for grooved seam; *F* half cylinders; *G* edges overlapped; *H* seam closed; *I* former expanded and *J* hinge.



slitting the tinplate on a gang-slitter into squared blanks, (2) feeding these blanks into an automatic body-making machine, usually with soldering attachments, and (3) double seaming the body-ends and bottoms for subsequent joining. Actually, all three operations may be simply divided into two sections: (a) body forming, and (b) the making of tops and bottoms. The modern practice is to use automatic plant for the former, with no hand manipulation after the insertion of the blanks in the hopper, a production speed of 300 soldered cylindrical-can bodies per minute being possible. In general practice the solder used consists of 30 parts tin and 60 parts lead.

After truing, the can bodies are double-end flanged (Fig. 1). For economy, can-ends are stamped in staggered pattern from the tinplate sheet, the strips being cut to shape

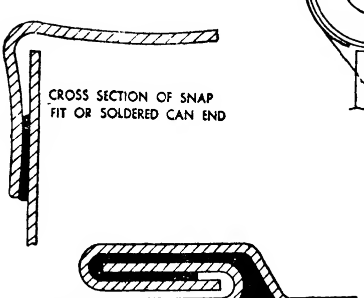
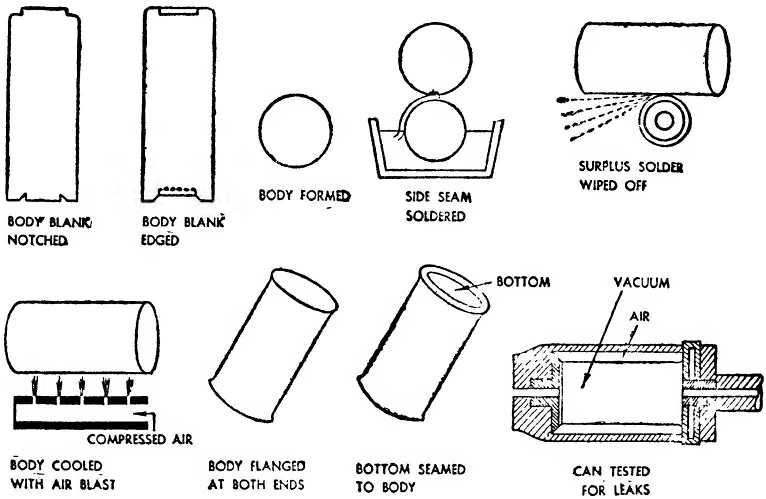


Fig. 2. (Above). Edge curling illustrated here is the final operation in can-making.



CAN-MAKING PROCESSES

Fig. 4. In can-making, a variety of processes is necessary. This illustration shows the procedure from the ready-cut blank to the air test of the finished can.

in scroll shears. Automatic strip-feed presses are then used for stamping can-ends to shape and size, the final operation being edge curling (Fig. 2). This last serves the triple purpose of (a) preventing nesting, (b) providing a receptacle for the sealing compound, and (c) protecting the sealing compound from injury in transit. After the can-end is sealed on, the container is ready for storage until it is ultimately filled with the required product, processed and closed by means of a double-sealing machine. The whole sequence is now largely automatic, and outputs can be given ranging from 60 per minute on self-contained plant to over 300 per minute on the type of machine described. With the latter, it is now usual to have elevators, conveyors and chutes made of sufficient length to preserve a reservoir of components in case any one machine is temporarily held up. These are equipped with electrical safety devices to stop all operations automatically in case of an overflow. The plant necessary in a fully equipped shop would be three gang-slitters, one high-speed body-making machine, a roll flexer, a double end-flanging machine, a multiple-head double-seaming machine (Fig. 3), compound applier, scroll shears and strip-feed presses equipped with edge-curling attachments. See GANG SLITTER.

CAPACITANCE. Symbol: C. The property of an electrical conductor which enables it to retain an electric charge. It is measured in farads. The term capacity (q.v.) is often used as a synonym. See CONDENSER and FARAD.

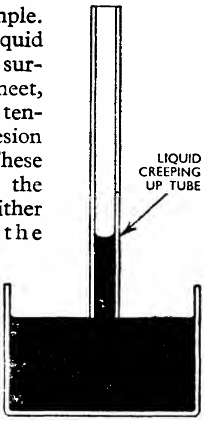
CAPACITOR, see CONDENSER (Radio).

CAPACITOR MOTOR. A split-phase type of electric motor which employs a condenser in series with one of the windings. This condenser may be cut out of the circuit when the motor has reached its normal speed. See MOTOR and SPLIT-PHASE.

CAPACITY. The rating of a piece of electrical machinery or apparatus, for example 100 kVA., or the quantity of electricity which can be delivered by a primary or secondary cell or battery at a specified rate, such as 60 ampere-hours at 10-hour rate. The term is also used as a synonym for

capacitance, e.g. the capacity of a condenser. See KILOVOLT-AMPERE and RATING.

CAPILLARITY. The name given to the phenomenon of which the rise or fall of liquids in a fine tube is an example. Where the air, liquid surface and the surface of the tube meet, forces of surface tension and adhesion come into play. These are balanced by the creep of liquid either up or down the



Liquids in small-diameter tubes tend to creep up the sides of the tube, as shown. This is known as capillarity.

tube, depending on whether the solid-liquid adhesion is strong or weak.

CAPSTAN LATHE. A lathe (q.v.) with a sliding and revolving turret which holds a number of tools, mounted in the order in which they will be required for carrying out a series of operations on the workpiece. Because lathes of this description can effect great economies in setting-up times over ordinary turning lathes, they are usually associated with mass-production work. The turret is generally hexagonal in plan, though it is occasionally made circular.

Many types of capstan lathe also incorporate a system of automatic stops for limiting the amount of travel of the turret carriage and cross-slide, so that the depth of hole to be bored, or the length of a thread to be chased, may not be exceeded; the adjusting of the stops is part of the setting-up operation before actual machining begins, and their use saves a great deal of time and prevents spoiled work.

CARBOHYDRATES. Compounds of carbon, hydrogen and oxygen, with the general formula $(CH_2O)_n$. They include the numerous sugars, starch, inulin, the dextrins, and cellulose, and they form a large part of all plants. There are many kinds of sugar, of which fructose, glucose, lactose, maltose and sucrose are the most important.

Fructose has the formula $C_6H_{12}O_6$, and is present in fruit juices and honey.

Glucose, or dextrose, also has the formula $C_6H_{12}O_6$; it is present in many fruit juices and in the blood of the higher animals. It is fermented by yeast, producing alcohol and carbon dioxide. It is largely used in brewing, in the manufacture of confectionery and in pharmacy.

Lactose, or milk sugar, $C_{12}H_{22}O_{11}$, is produced from starch and is fermented by yeast. Its constitution is that of two glucose rings joined together.

Maltose, $C_{12}H_{22}O_{11}$, is also produced from starch and fermented by yeast.

Sucrose or cane sugar, again with the formula $C_{12}H_{22}O_{11}$, is a disaccharide composed of a glucose unit and a fructose unit joined together. Sucrose is readily broken up into glucose and fructose by dilute acids or by ferments; cane sugar and beet sugar are chemically identical.

Starch is contained in plant cells and specially in rice, flour, and potato tubers. It has the general formula $(C_6H_{10}O_5)_x$, where x is a large and indefinite number; it is believed to consist of long chains.

Each ring is a glucose unit, and treating starch with a dilute acid forms glucose alone. When broken down by enzymes, starch forms units of two glucose rings joined together as in maltose. When it is heated and treated with acids it forms British gum, a mixture of various dextrins.

Inulin $(C_6H_{10}O_5)_x$, takes the place of starch in the tubers and roots of the Jerusalem artichoke, dandelion, and other members of the family of Compositae. It consists of chains of fructose units.

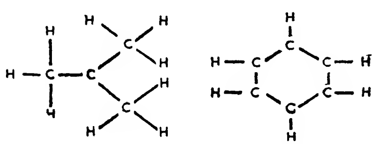
Cellulose, see article under that heading.

CARBON (C). Atomic no. 6; atomic wt. 12·010. An element which occurs

in nature in two crystalline forms, diamond and graphite, and, in amorphous form that is not quite pure, in anthracite coal. Charcoal is nearly pure carbon; lampblack, soot and gas carbon are not so pure.

Diamond (q.v.) is transparent, has a density of 3·52, a high refractive index, and is very hard. It crystallizes in the cubic system. *Graphite* (q.v.), also known as plumbago (q.v.) and black lead, has a density of 2·2, it is not transparent, is soft and easily split into flakes. It crystallizes in the hexagonal system.

Carbon is a tetravalent element with four external electrons, and is remark-



Structural-formula diagrams for compounds of carbon and hydrogen, which are generally known as hydrocarbons.

able for the ease with which one carbon atom will combine with another. Thus, there are very many compounds of carbon and hydrogen, called hydrocarbons, of such types as are shown at (a) in the accompanying diagram.

This is in addition to an enormous number of compounds in which six groups of CH are arranged in a hexagon, as in benzene, shown at (b).

There is a limited number of hydrocarbons. Of the many thousands of carbon compounds it is possible here to mention only a minute fraction.

Carbon forms two oxides, both gases, carbon monoxide, CO, and carbon dioxide, CO_2, the former being very poisonous. The dioxide dissolves in and combines with water to form an acid, carbonic acid, H_2CO_3, and this reacts with many metals to form carbonates, such as calcium carbonate (chalk), $CaCO_3$, sodium carbonate, Na_2CO_3, 10 H_2O (washing soda), magnesium carbonate, $MgCO_3$, and so on.

Carbon combines with sulphur to form carbon disulphide, CS_2, a colourless liquid that is an excellent solvent for oils, waxes, rubber and phosphorus.

It combines with chlorine to form carbon tetrachloride, CCl_4, and with hydrogen and chlorine to form chloroform, $CHCl_3$. With iodine and hydrogen it combines to make iodoform, CHI_3, with nitrogen to make the gas cyanogen, C_2N_2, which combines with hydrogen to form hydrocyanic acid (prussic acid), HCN; this acid gives rise to a series of cyanides, of which potassium cyanide, KCN, is well known.

Another derivative of cyanogen is potassium ferrocyanide, $K_4[Fe(CN)_6]$ $3H_2O$, from which Prussian blue can be prepared. Carbon combines with iron to form steel, and with calcium to form calcium carbide, CaC_2, used in the production of aceytlene. Every plant tissue, and every animal tissue, is made up of compounds of carbon, and a very important class of compounds is that of the CARBOHYDRATES. The carbonyls are compounds of carbon monoxide with a metal, e.g. nickel carbonyl, $Ni(CO)_4$, of importance in the manufacture of nickel. The aniline dyes and most of the modern dyestuffs are compounds of carbon. The chemistry of the carbon compounds is so large a subject that it forms a distinct branch of chemistry called organic chemistry. See also BENZENE and PETROL.

CARBON BLACK. The non-metallic element carbon in the form of a dry, soft powder, used as a pigment. In combination with extenders such as white lead, (q.v.) asbestine (q.v.) and barytes (q.v.) it forms the solid portion of a kind of black linseed oil gloss-paint with good drying qualities.

CARBON BRUSH, see BRUSH.

CARBON MICROPHONE, see MICROPHONE.

CARBON MONOXIDE. A poisonous gas produced by the combination of carbon and oxygen in a certain proportion when there is not enough air for complete combustion. The

exhaust gases from a petrol engine contain some carbon monoxide and if an engine is run in a confined, unventilated space, such as a small garage, this gas is liable to be present in dangerous quantities, particularly if the air/petrol mixture is rich.

CARBON TISSUE. A paper used in the photogravure printing process, covered with a regular coating of gelatine in which an insoluble orange-brown pigment is evenly distributed. It is sensitized in a solution of bichromate of potash, the photographic positives or type printed upon it, the resultant film developed, and the whole transferred to the copper cylinder or plate. It then becomes resistant, in degrees varying with the solubility of the light-hardened areas of the film, to the acid used for etching the image into the copper.

CARBORUNDUM. The trade name given to silicon carbide. Carborundum was first formed by Edw. G. Acheson in 1891. It is a manufactured abrasive made in electric furnaces of the resistance type. The materials used in the manufacture are coke (supplying the element carbon), silica sand (supplying the element silicon) sawdust and salt.

The mixture surrounding the electrodes is heated to a temperature of approx. 4000 deg. F., when the carbon of the coke combines with the silicon of the sand to form silicon carbide. The sawdust makes the mixture porous so that the carbon monoxide gas formed during the furnace-run can escape freely, and the salt combines with the various impurities in the coke and sand to form chlorides which can be eliminated from the crude carborundum.

At the end of the furnace-run the outer crust and the crystalline materials surrounding the furnace elements are removed. These masses of the crude abrasive are then crushed to desired sizes and subjected to various purifying treatments, and the product is graded into grain sizes. Carborundum is the hardest known synthetic abrasive, and is indeed one of the hardest materials yet discovered, taking second place only to the diamond.

The crystals always fracture irregularly, and so constantly present new, sharp cutting edges to the work being ground. Grinding wheels of this material are generally used for grinding hard, brittle materials such as grey-iron castings, chilled iron, cemented carbide tools, hard alloys, marble, stone and ceramic materials, and those of low tensile strength such as brass and soft bronze, copper, rubber and leather. Carborundum is also used extensively as a refractory, on account of its high heat-resisting properties.

CARBORUNDUM STONE, see OILSTONE.

CARBURETTOR. A device for metering or controlling the correct amount of liquid fuel to be mixed with the air entering the cylinders of a petrol engine on the induction stroke. The fuel issues in a finely divided, or atomized, spray and devices are incorporated to deal with the varying engine conditions.

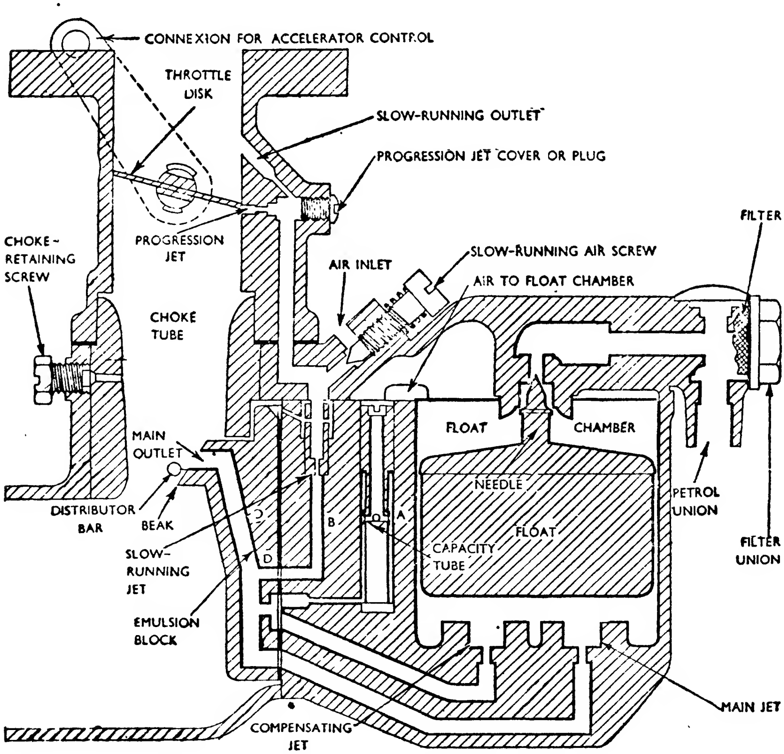
The simplest form of modern carburettor consists of a float chamber and petrol jet, the orifice of the latter being situated in the throat, or narrow portion, of a choke tube through which the air passes on the induction stroke. The increased speed of the air through the narrow portion of the choke tube causes the pressure therein to fall below the pressure of the atmosphere. This difference of pressure forces the petrol out of the jet in the form of a spray to mix with the incoming air.

Detailed consideration of the best air/petrol mixture for complete combustion at different engine speeds, however, makes the modern carburettor a far more complicated unit. The chief difficulty lies in the fact that, at different speeds, the depression in the induction pipe has different values, whereas a rich mixture of air and petrol may be required at both ends of the scale; i.e. for starting and full speed.

To overcome these difficulties, most modern carburettors make use

of a number of jets of varying size, so arranged that they come into action automatically as required; and successful design demands the most careful attention to the proportions of orifices and ducts.

The simplified diagram below shows the working of a modern Zenith carburettor. Petrol enters at the petrol union, passes through the filter, and descends into the float chamber around the needle valve on top of the float. As the float rises, this needle valve closes the orifice, thereby maintaining the petrol at a certain level. At this level, the fuel, having passed through both the main jet and compensating jet, has risen in the capacity tube and in the tubes leading to the slow-running jet and emulsion block. The continuation of tube B gives access both to the slow-running and progression outlets, while there is an air inlet for extra air controlled by the slow-running air screw. The float chamber and tube C are in communication with atmospheric pressure by the duct indicated and, with the throttle disc in the position shown, the carburettor is ready for starting or slow running. That is to say, the induction pipe is closed, and any suction from the movement of the pistons must draw petrol from the slow-running outlet. Easy or smooth running is obtained by adjusting the slow-running air screw. Air is drawn in at this air inlet while the throttle is in the closed position, and mixed with the petrol sucked up from the tube B.



TYPICAL MODERN CARBURETTOR

Sectional view of a carburettor as fitted to the petrol engines of many road vehicles ; the arrangement of the jets and fuel-controlling devices is shown.

Now, as the throttle is opened for faster running, there is a moment when the engine is drawing air through the main choke tube, but is failing to draw petrol from the main outlet until sufficient suction has been created to raise a head of petrol in tube A, the level being arranged to remain just below the outlet while the engine is idling or stationary. For this reason the progression jet, or temporary compensating jet seen just below the right-hand side of the disk valve, comes into operation to keep the air/petrol ratio constant. As the engine picks up, however, the depression created in the narrower part of the choke tube, draws fuel from the main outlet, and this fuel is already mixed with air drawn downwards through tube C from the air inlet to the float chamber. This air meets the petrol from the compensating jet at the junction D and partly atomizes it.

Distribution of fuel throughout the air and petrol mixture is assisted by the beak of the main outlet and the distributor bar. An area of low pressure is created above this bar, which tends to spread the fuel evenly along it, so that the mixture as eventually supplied to the engine is even in quality.

There are many other types of carburettor, notably the Amal, the Solex and the S.U., but the underlying principles are the same. Automatic control of the mixture is obtained at varying engine speeds by the varying suction through the choke tube, although the means or devices by which this is accomplished are not always the same.

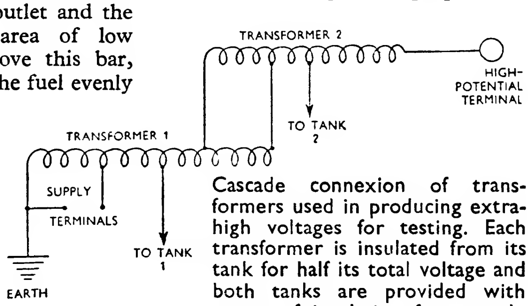
CARRIAGE, see STAIRS.

CARRIER WAVE. A radio-frequency wave which is modulated by, and acts as a carrier for, speech and music frequencies.

CARRIER-WAVE TELEGRAPHY A system of electric signalling in which a number of sets of signals each modulate a different carrier frequency. The modulated carriers may be transmitted by means of a single circuit and selected at the receiving-end by means of electrical filtering networks. After demodulation the original signals are available separately. See CARRIER WAVE, MODULATION and DEMODULATION.

CARTRIDGE STARTER. A method of starting petrol and oil engines by means of an explosive charge. In aircraft, the system consists of a suitable breech for firing a cartridge, connected to a cylinder containing a piston which is depressed by the gases generated by the explosion. The linear motion of the piston is converted, by means of a screw thread, into rotary motion which, in turn, is transmitted to the engine through a conventional starter dog-clutch.

CASCADE. A method of using two electrical induction motors which have different numbers of poles, in order to obtain speeds appropriate to the sum and difference of the numbers of poles as well as the two primary speeds.



Cascade connexion of transformers used in producing extra-high voltages for testing. Each transformer is insulated from its tank for half its total voltage and both tanks are provided with means of insulation from earth.

A method of auto-connecting transformers, as shown in the diagram, which is used in the production of very high voltages for testing purposes. It is much easier to insulate a tank to withstand high voltages than it is to insulate a winding from its tank for the same voltage. See AUTO-TRANSFORMER and SYNCHRONOUS SPEED.

CASED WINDOW FRAMES. Boxings made from pieces of timber $\frac{3}{4}$ to $1\frac{1}{2}$ in. thick, used exclusively for

sliding sashes, and often termed *boxed frames*. The posts and head of the frame are built up to form boxes, in the vertical parts of which counter-balancing weights travel, the weights being connected to vertically moving sashes by means of cords or metal chains (see WINDOWS).

Each sash slides in its own pair of grooves and has its own set of pulleys and counter-balancing weights. Sashes of this type are known as *double-hung sashes* in cased frames. The top sash is always the outer one. The horizontal bottom member is termed a *sill*; the vertical members or posts are known as *pulley stiles*, because the pulley through which the cord is wreathed is fitted in the top part of the stile; and the top member is termed a head.

CASE-HARDENING. A method of treating low-carbon steel, containing 0·15 to 0·20 per cent carbon, so that a hard, thin outer case is formed over a tough internal core. Machine and engine components frequently have to be sufficiently tough to withstand shocks and high stresses, yet hard enough to give low rates of wear. Maximum hardness and toughness in steel cannot be achieved together; a compromise must be sought so that both properties are sufficiently developed for best operating results.

The case is formed by increasing the percentage of carbon in the outermost layers by heating the steel to the correct temperature in contact with a carbonaceous medium and then quenching it. To raise the carbon content a carburizing process is carried out, involving the impregnation of the external surface with carbon, after which controlled heat treatment of the carburized surface takes place; this hardens the outer surface and at the same time imparts the desired characteristics to the core.

Articles to be case-hardened are usually packed into metal boxes, which are sealed and then heated in an oven; here they are kept at a temperature of about 1,650 to 1,830 deg.F. for a period dependent upon the degree of carburization needed. The carburized steel then undergoes its heat treatment, which involves heating followed by quenching. Owing, however, to the dual nature which the steel has by now acquired, quenching must be followed by rehardening. There are two chief methods. In the first, quenching direct from the metal box, followed by rehardening at 1,400 to 1,450 deg. F., produces a refined structure for the case and a tough core. In the second, the articles are allowed to cool first while in the box; they are then rehardened at approximately the critical temperature of the core—1,550 to 1,650 deg. F., quenched, and rehardened at the critical temperature of the case, 1,400 to 1,450 deg. F. The latter method gives maximum refinement of both case and core; moreover it reduces to a minimum the warping, i.e. distortion, due to internal strains, which forms one of the chief practical difficulties of case-hardening.

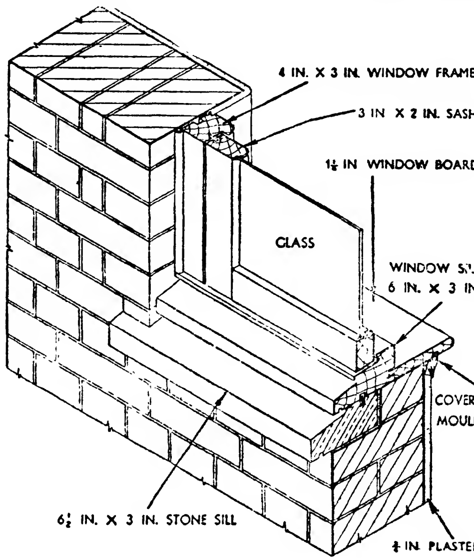
CASEIN. The principal protein of milk. It is a white amorphous powder, insoluble in water, but soluble in acids and alkalis. It is manufactured by treating cows' milk, and is used in the manufacture of plastics, in the food and drug industries, the paint and paper industries and others. Casein plastics are prepared by mixing powdered casein with water and fillers, pressing into shape, and hardening with formaldehyde. The best known include Erinoid, Galalith, and Lactoid.

In powder form, mixed with powdered lime and colouring matter, casein produces a type of washable distemper supplied dry for mixing with water only. The reaction between the casein and free lime produces a film which is difficult of re-solution with water when dry. It is used in the printing industry in adhesives, as a sizing agent in coated boards and paper, and as a substitute for albumen as a light-sensitive colloid in lithography and photo-engraving.

CASEIN GLUES, see GLUE.

CASEMENT WINDOWS. Solid-frame windows with opening sashes, hinged vertically or horizontally, with sill, (q.v.) posts, stiles, head, mullions

Sectional view of casement window. Note groove in sill to prevent penetration of damp to interior.



and transoms. They may have any number of lights grouped within the frame, but four to six is usual. Casements are now often made of metal, the members usually being of rolled-steel, or alloy, section. Where wood is used, however, the frame is of solid timber 2½ to 3 ins. thick by 4 to 5 in. wide, and is provided with rebates for the accommodation of the sashes, similar to those of a door frame.

A system of throating, or grooving, prevents the penetration by capillary action of rain water to the interior. The sashes are either fixed to the frame or are hinged to open inwards or outwards, the latter being more satisfactory for keeping out driving rain. The sill should be of teak or oak and weathered, double-sunk, throated and ploughed for the window board.

CASTING. In metallurgy, either the operation of pouring liquid metal or other material into a mould to form a required shape, or the object so formed.

Metal castings, chiefly of iron, are made in sizes varying from a few pounds in weight to several tons. The principal defects likely to be encountered are blowholes, shrinkage cavities, porous places, cracking, scabs and cold shuts.

Blowholes are caused by gas trapped in the metal. The surface of a blowhole has a shiny appearance, quite different from the rough and crystalline effect produced by internal shrinkage cavities.

Surface imperfections due to shrinkage are likely to be found where a thin section joins a heavy part of the casting, and can be avoided by the use of chills or by increasing the size of the feeding heads. Minor forms of shrinkage may cause porosity, resulting in failure under the water test. Leakage may also occur round chaplets used to provide additional support.

Cracking may be due to excessively tight ramming, which prevents the casting from contracting naturally in the mould; or to unsatisfactory design. Cracks, resulting from bad design, are likely when an abrupt change of section occurs.

Scabs are largely due to unsatisfactory venting. The expansion, in the mould, of gases which are unable to escape rapidly enough, blows the metal away from the mould face. This has already been weakened by the high temperature to which it has been subjected and, being no longer supported by the metal, may collapse, causing a scab on the surface.

Cold shuts are caused by the meeting of two different streams of metal in the mould after they have almost solidified, so that they do not unite properly.

CAST-IRON. Iron containing so great a proportion of carbon that it is not malleable at any temperature. Whilst this would theoretically include

irons having a carbon content as low as 2·2 per cent, in practice the figure is usually between 3 and 4 per cent.

If the carbon is present as the free element in the form of graphite, the iron is called grey cast-iron; if the carbon is present in the combined form, cementite, the iron is known as white cast-iron. Frequently, however, a mixture of both forms is encountered.

The material is used in preference to all other metals for parts to be formed by casting, or for purposes in which there is no objection to weighty construction. As it is weak in tension as well as being brittle, it should not be employed for components liable to shock or strain. It is cheap, and also has the merit of forming a good bearing surface; should continuous wear be contemplated it will be found that a much longer period of service can be obtained if the surfaces are chilled.

The ultimate compressive stress of ordinary cast-iron may be taken as 80,000 to 100,000 lb. per sq. in.; the tensile strength as only 18,000 to 22,000 lb. per sq. in. The modulus of elasticity varies from 12,000,000 to 16,000,000 lb. per sq. in. Its specific gravity is 7·2 and its weight per cubic in. 0·26 lb. Cast-iron melts at about 1,200 deg. C.

Certain special high-duty cast-irons are now widely used for special parts, their strength being increased to as much as 65,000 lb. per sq. in., by the addition of various alloying elements such as chromium, copper, nickel or molybdenum. See AUSTENITIC CAST-IRON; GREY CAST-IRON; HIGH-DUTY CAST-IRONS; MALLEABLE CAST-IRON (BLACKHEART); MALLEABLE CAST-IRON (WHITEHEART) and WHITE CAST-IRON.

CASTORING. The rotation of the landing wheels of an aeroplane about a vertical, or almost vertical, axis. If nosewheels and tailwheels were fixed in the fore and aft plane of an aircraft they would have to skid sideways during ground manoeuvring. This would cause excessive tyre wear; such wheel assemblies are, therefore, made to rotate about an axis which is vertical or nearly so.

CATALOGUE CAPACITY (Plumbing), see CISTERN.

CATALYSIS. The speeding up of a chemical process by the addition of small amounts of a substance, known as a catalyst, that seems to be unchanged by the process. Thus, sulphur dioxide, SO_2, and oxygen combine very readily to form sulphur trioxide, SO_3, in the presence of finely divided platinum, which remains unaffected.

The hydrogenation of fats to make margarine is greatly assisted by the presence of finely divided nickel. The decomposition of potassium chlorate, $KClO_3$, to yield oxygen is assisted by the presence of a small quantity of manganese dioxide. All these catalysts may be recovered at the end of the process. In the manufacture of phthalic anhydride by heating naphthalene with sulphuric acid, a poor yield was obtained until, by accident, a broken thermometer was inserted in the vessel and a little mercury escaped; the mercury sulphate then formed acted as a catalyst, and the process became very successful and profitable. It is supposed that the catalyst forms with the reactants a temporary compound that immediately breaks up into the reaction products. Catalysts are used in many industrial operations.

CATAPULT. A means of rapidly accelerating an aircraft from rest to flying speed, and so permitting its operation from restricted spaces, such as the decks of battleships, cruisers and even merchant ships. The aircraft is supported on a trolley which is propelled along a track by a compressed air ram or by the explosion of a cordite charge. When the trolley reaches the end of a track it is brought suddenly to rest, and the aircraft, now travelling at a speed adequate for flight, leaves it. Aircraft have to be specially strengthened for catapult launching to withstand the very high acceleration involved.

CATHODE. The electrode at which an electric current leaves a liquid, a

gas or a vacuum. In radio, the negative electrode of a thermionic valve, that is, the electrode from which electrons are emitted. See RADIO VALVE.

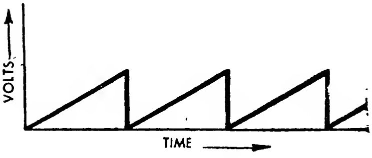
CATHODE BIAS, see AUTOMATIC GRID BIAS.

CATHODE INJECTION. A frequency-changing system in which the output of an oscillator valve is introduced into the cathode circuit of a mixer valve.

CATHODE-RAY OSCILLOGRAPH. A device by which voltages or electric currents are made to form a trace of light on a screen. The dimensions of the trace may be used as a measure of the applied voltage or current, the shape or pattern indicating the frequency and wave-form. The actual indicator is a cathode-ray tube which consists of an evacuated glass vessel in which the beam of electrons emitted from the heated cathode is made to impinge on a fluorescent screen. The impact of electrons, which in practice are focused to a point on the screen, causes the coating material to glow.

The beam may be deflected electrostatically or electromagnetically in a horizontal or vertical direction, in which case the visible trace would be a simple line.

The real value of the cathode-ray oscillograph lies, however, in the analysis of varying or alternating



" Saw-tooth " wave-form provided by the time-base circuit and applied to the cathode-ray tube for the purpose of horizontal deflection—see text.

quantities. For this purpose, a " saw-tooth" voltage generated by a valve apparatus called a "time base" is applied to the horizontally deflecting plates. The steady rise of voltage swings the spot from left to right so that it moves across the screen at a constant linear velocity. The sudden fall of voltage causes the spot to return from right to left almost instantaneously. This process is repeated indefinitely.

The voltage whose wave-form is to be examined is now applied to the vertically deflecting plates and the repetition frequency of the time base is adjusted, and when this equals the frequency of the oscillation under examination, a trace showing its wave shape appears. For example, if a 50-cycle supply main is applied to the vertically deflecting plates and the time base adjusted to 50 horizontal sweeps per second, successive cycles will be traced indefinitely over the same part of the screen. Owing to the persistence of the fluorescence and of vision, an apparently stationary picture will be seen.

For the examination of electric currents, the deflection would have to be electromagnetic, and thus deflecting coils, external to the tube, would be used in place of plates. Other applications of the cathode-ray oscillograph are extremely numerous, ranging from the investigation of all kinds of vibrations and transients to the study of atmospheric conditions; it is also employed in recording the performance of all kinds of electrical and mechanical apparatus. See CATHODE-RAY TUBE.

CATHODE RAYS. Beams of electrons; an emission from a cathode enclosed in a vessel which contains little or no gas and evoked by the influence of a positive electrode acting as an anode. Cathode rays are readily produced from a hot cathode and may also be radiated from a cold one in the presence of gas at a low pressure. Their effects are several and include mechanical effect, by which the rays or moving electrons exert pressure on any solid object in their path, and heating effect, which is exhibited by a rise of temperature of the material on which they fall.

Because of their nature, cathode rays are capable of being influenced or deflected by electromagnetic and

electrostatic fields. Probably the most important application of these rays at the present time is in the cathode-ray tube. See CATHODE-RAY OSCILLOGRAPH and CATHODE-RAY TUBE.

CATHODE-RAY TUBE. An electronic device consisting essentially of three main parts: (1) an electron "gun" for producing a thin beam of fast-moving electrons, called cathode rays, (2) a fluorescent screen which produces a luminous spot when cathode rays impinge upon it and (3) a means of deflecting the beam.

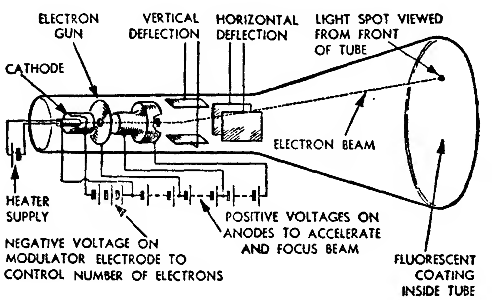


Diagram showing construction of a typical cathode-ray tube.

The construction of a cathode-ray tube with provision for electrostatic deflection is shown in the illustration. The electron gun comprises a hot cathode, as a source of electrons, and a modulator, or control electrode, to determine brightness of the spot. Positive voltages applied to specially shaped anodes accelerate and focus the beam which impinges upon the fluorescent coating on the end of the tube.

The fluorescent materials or *phosphors*, include willemite (zinc orthosilicate) which emits green light; zinc oxide, blue light; zinc beryllium silicate, yellow light; and a mixture of zinc sulphide with cadmium zinc sulphide or zinc beryllium silicate which emits nearly white light and is often used in television tubes. The application of a voltage to either the vertical or horizontal plates causes the beam to be correspondingly deflected. See CATHODE RAYS.

CATHODE-RAY TUNING INDICATOR. A miniature cathode-ray tube, incorporating a triode valve and controlled by the automatic gain control (q.v.) circuit of a radio set. It is used to indicate when the receiver is correctly tuned. By means of differently shaped electrodes, it is possible to obtain special effects which give rise to such names as the "Magic-Eye" indicator.

CATION, see ELECTROLYSIS.

CAULKING. A method of making joints water- or steam-tight. The seams of a wooden carvel-built ship are caulked with rope yarn and afterwards filled with white lead, pitch or a patent filler; the overlapping joints of an iron-built ship or riveted boiler are caulked with a chisel by hammering the ends of the plates and gently forcing them together.

In plumbing, joints are first caulked with yarn or gaskin, and then filled with molten lead, lead wool or rope. When molten lead is used the liquid metal is poured in to the joint space, allowed to set, and then hammered up tightly with a caulking tool. Lead wool or rope is used where it is inconvenient or impossible to make the joint with molten lead, as on a pipe through which water is circulating.

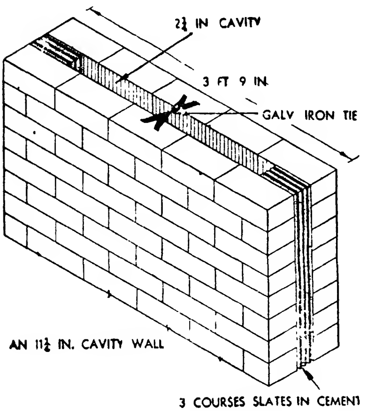
In this case the lead is caulked-in strand by strand until the jointing space is full. The tools used are a hammer and a caulking tool, the latter being blunt in form and of either hardwood or iron.

CAVITY WALL. A wall consisting of two separate walls divided from each other by an air space which is usually $2\frac{1}{2}$ in. wide. The purpose of the cavity is to ensure dryness of the interior wall and to obtain a more constant temperature within the building.

The walls may be of any thickness but for domestic buildings comprising two floors they are usually $4\frac{1}{2}$ in. thick. For higher buildings, however, the

interior walls are increased in thickness.

The provision of the cavity is especially recommended if the face of the wall is exposed to driving rains. The cavity may be ventilated by the



In an 11¼-in. cavity wall, there is an air space 2¼ in. wide between the two separate walls to ensure dryness.

provision of air bricks built in the lower and upper parts of the external wall. Rigidity of the walls is assisted by placing specially designed wall-ties across the cavity throughout the length and height of the wall.

CEILING. A term used to describe the peak value of a varying quantity. In connexion with aircraft, there are three ceilings, as follows: The *absolute* ceiling: the altitude at which the rate of climb is zero; the *service* ceiling: the maximum altitude obtainable in practice, usually taken to be that altitude where the rate of climb is 100 ft. per minute; and the *operational* ceiling: the maximum altitude at which the aircraft can efficiently perform its duties.

CEILING (Building). The upper surface of a room, or the under surface of a floor; may be constructed of laths and plaster, plaster-board sheets, pressed-fibre board or match-boarding.

CEILING JOISTS. Light timber beams which carry the laths for plastering a ceiling or the plaster-board which may be used to form the ceiling. Ceiling joists are used in double and framed floors for firring—to provide a fixing for the material forming a suspended ceiling when a level surface is desired. They are spaced 14 in. apart if the ceiling is to be formed with lath and plaster, and about 18 in. apart if sheets of plaster-board are to be used.

CELLOPHANE. Although this is the registered trade mark of British Cellophane, Ltd., the word is often wrongly used to indicate all transparent films of the cellulose (q.v.) type.

Cellophane has practically nothing in common with paper, except that the raw stuff is cellulose and the final product is a thin flexible sheet. Cellulose is separated from the lignins and unwanted materials of wood and made soluble by chemical treatment. The syrupy solution is extruded through orifices whose degree of fineness controls the thickness of the resulting sheet. Further chemical treatment solidifies this liquid stream, and the resulting transparent, glossy, homogeneous, odourless cellulose film is Cellophane.

It is made in sheet or reel form, plain and in many colours, and may also be embossed. It is readily affected by moisture and heat, but can also be made in a moisture-proof variety, supplied in waxed-paper wrappers for various purposes.

Cellophane is used as wrapping for confectionery, food and cigarettes; as a decorative aid; as envelope windows and like applications, and as a reinforcement for glass against percussion.

CELLULOSE. A carbohydrate, $(C_6H_{10}O_5)_x$, contained in the cell wall of plants; it is the main constituent of cotton and other vegetable fibres. In its natural form, after mechanical breaking down, cleansing and bleaching, cellulose forms the fibrous structure of paper. It consists of long chains of glucose units joined together.

Strong acids break up cellulose into glucose units; weak acids break it up

into units consisting of groups of glucose rings.

Cellulose forms a number of compounds (esters) when treated with acids under suitable conditions. Several of these are used largely in industry.

Viscose, a variety of artificial silk, is made by treating cellulose with carbon disulphide so as to make a liquid which, when spun into a bath of dilute sulphuric acid, forms a solid thread.

Cellulose Nitrate, or nitrocellulose, is prepared by treating cellulose with nitric acid and sulphuric acid. A special variety of it, the hexanitrate, is the well-known explosive guncotton, which forms the principal part of the modern cordite.

Collodion is a solution of nitrocellulose in a mixture of alcohol and ether, which forms films used in surgery; it was formerly much used in photography.

Celluloid and *Xylonite* are made by treating nitrocellulose with camphor and alcohol; they are important plastics when treated with the necessary solvent and plasticizer.

Cellulose Acetate was formerly the dope used almost universally for aeroplane wings, but other substances are now suitable. The acetate is also manufactured on a large scale as rayon, or artificial silk, and for films. Other derivatives of cellulose are used as varnishes.

CELLULOSE ACETATE, see CELLULOSE.

CELLULOSE LACQUER. Cellulose in solution, to which has been added resin to improve its grip upon the surface to which it is applied, plasticizers to give elasticity and flow, and a diluent (q.v.) with characteristics similar to those of alcohol. It may be dyed to give colour but still retain its transparency, or be pigmented to render it opaque and so obscure the ground or priming upon which it is placed. The lacquer becomes a solid continuous film by the evaporation of its liquid content.

Owing to the very volatile character of the material and its solvent action upon previously applied coatings, a film of satisfactory thickness is best built up by spraying, and the final gloss developed by pulling over with a soft pad and the diluent as in French polishings. The dry film grips firmly any clean and sand-blasted metallic surface without further preparation, but on timber it is usual to prime first with a hard-drying oil primer.

CELLULOSE NITRATE, see CELLULOSE.

CEMENT. In general, any substance used for uniting materials or articles; the term is usually applied, however, to those which form a plastic mass when mixed with water, and set hard on standing. These are properly called hydraulic cements. Portland cement (q.v.) is made by calcining chalk or limestone with clay or other material containing silica and alumina.

Selenitic cement is similar, but contains about 5 per cent of plaster of Paris. Ciment fondu is made by calcining a mixture of limestone and bauxite, and is highly resistant to seawater.

Cements are also widely known by their characteristics: for instance, acid-resisting and quick-setting cements. Refractory cements are used in furnaces and will withstand great heat.

CEMENTATION PROCESSES, see METALLIC COATING.

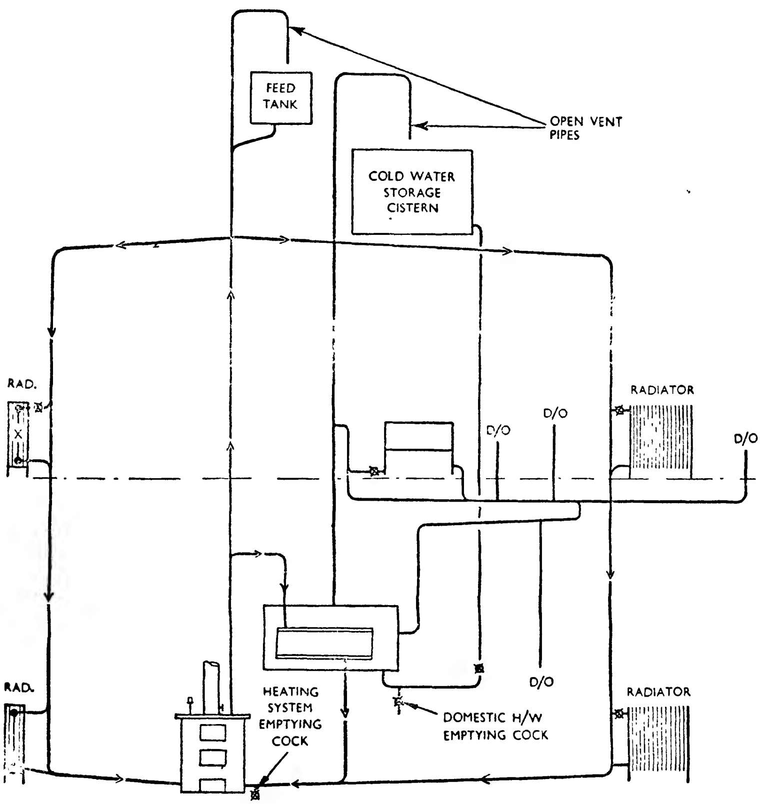
CEMENTITE. Iron carbide, Fe_3C; a normal constituent of annealed steels and cast-iron. It may occur either as lamellae in the constituent pearlite, in both steels and cast-iron, or in massive form in steels containing over 0·87 per cent carbon. Prolonged heating of steels at 600 to 650 deg. C. converts cementite occurring in the pearlite into globular form, especially if the steel has been cold-worked.

In cast-irons it is again present in the form of pearlite. White cast-iron, in addition, contains considerable quantities of free cementite. Iron carbide is a very hard and brittle material, but when present in the lamellar form, as in pearlite, considerably increases the strength of

steel without seriously impairing the ductility.

CENTRAL HEATING. A system of heating in which the heat comes from a central source. There are three main systems, namely, hot air, hot water and steam. In some cases superheated steam may be used, but this method requires a great deal of upkeep, and the initial outlay is

In the hot-water method, the layout is similar to that of the average hot-water system, save that the fitting of radiators requires the provision of return pipes to the boiler. The illustration gives an idea of the indirect hot-water system used for heating purposes, with the radiator supply tapped off the primary flow-and-return to the neutral boiler.



CENTRAL-HEATING SYSTEM FOR TWO-STOREY HOUSE

Layout of a central-heating and domestic hot-water installation, which, it will be seen, incorporates an indirect heating unit in addition to the ordinary boiler.

considerable, all joints and fittings needing to be capable of withstanding high pressures. In Britain, the hot-air system, in which hot air rises through gratings and warms the atmosphere, is confined to churches and halls.

In all systems where there are no direct flues to draw off the foul air, provision must be made for ventilation. Lack of proper ventilation may lead to the heating system itself being termed unsuitable or unhealthy.

The indirect hot-water system gets its name from the fact that the domestic hot-water supply is provided by water already heated in the main boiler, or fuel burner, as will be seen from the illustration.

CENTRE OF BUOYANCY. The point within a floating mass or object through which the force of buoyancy supporting the mass is assumed to act; when the mass is in equilibrium (at rest) the sum of the moments of the forces of buoyancy acting on every part of it is zero, and the centre of buoyancy is coincident with the centre of gravity of the liquid or gas displaced by it. See METACENTRE.

CENTRE OF GRAVITY. The point at which the force of gravity is assumed to exert its influence on a mass or body; the point at which a mass could be suspended and remain perfectly balanced in any position; the point about which the algebraic sum of the moments of the weights of each individual part of a composite body, for instance, an aeroplane, is zero.

CENTRE OF PRESSURE (Aero Engineering). The point at which the lift and drag forces on an aerofoil, in reality distributed all over the surface, may be assumed to be acting at any particular time, i.e. the point about which the pitching moment is zero.

For most aerofoils, however, the position of the centre of pressure varies with the angle of incidence; being farthest forward at the stall and farthest aft in a dive.

A symmetrical aerofoil, or one with a suitably reflexed trailing edge, has a stationary centre of pressure. The centre of pressure coefficient CC.P. defines the position of the centre of pressure along the chord line. For example CC.P. = O.4. means that the centre of pressure is 40 per cent of the chord back from the leading edge.

CENTRES, see TEMPORARY TIMBERING.

CENTRIFUGAL AND CENTRIPETAL FORCE. *Centrifugal* force is the force which, when an object is being rotated about a point tends to move that object outwards, that is away from the centre of rotation. *Centripetal* force is the force which has to be exerted to keep the same object in its orbit. If a weight be whirled round on the end of a piece of string, the weight is exerting centrifugal force and the string, which contains it within its orbit, is exerting centripetal force.

CENTRIFUGE. An apparatus consisting of a basket into which a mixture of solids and a liquid or of two liquids of different specific gravities is fed; as the basket is rotated at a high speed the liquid is thrown out through the holes in the basket, leaving the solids in it almost dry. This principle is employed in the apparatus used in dairies for separating cream from milk.

CENTRIPETAL FORCE, see CENTRIFUGAL AND CENTRIPETAL FORCE.

CERIUM (Ce). Atomic no. 58; atomic wt. 140·13; a metal of the rare-earth group, obtained from monazite sand; density 6·75; m.p. 815 deg. C. It is trivalent. An alloy of cerium, lanthanum and other rare-earth metals with iron, when scratched with iron, sparks, and is used as flints in gas lighters and cigarette lighters.

C.G.S. SYSTEM OF UNITS. A fundamental system of units based on the centimetre, gram and second.

CHALKING. A film of unattached pigment upon a painted surface, caused by the gradual disintegration of the binding medium in the paint. Exposure to extreme climatic conditions, with bright sunlight and nearness to the sea, are the usual causes. The action of a pigment upon the medium is an exceptional cause. The use of an elastic varnish in place of linseed oil for the final coating is a good preventative measure.

CHALK OVERLAY (Printing). A stained paper sheet, used in making-ready, or preparing, formes for printing on the machine. This paper has a chalk preparation on both sides. Impressions of the half-tone block which is to be printed are taken on both sides of the paper in register and with an acid-resisting ink. Etch is then

applied, and the chalk is gradually removed from the parts not inked, until the tinted paper is exposed. This is dried and is stuck carefully in place on the cylinder where it serves to give a graded pressure which is heaviest in the solids. See MAKE-READY.

CHANGE GEARS, see CHANGE WHEELS.

CHANGE WHEELS (Mech. Engineering). Gears provided on screw-cutting lathes to connect the lathe spindle stud and the lead screw. Before the modern, quick-change gear device was applied, every screw-cutting lathe was furnished with a complete range of gear-wheels for cutting threads of different pitches. The gear-wheels to be used for a given thread were calculated as follows: the number of threads per inch which were cut when gears of equal size were placed on the lead-screw and spindle stud were first determined by trial.

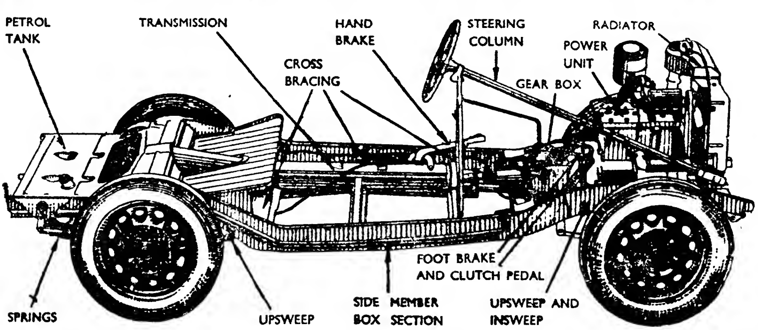
Call this number the numerator of a fraction, the denominator being the number of threads per inch to be cut. Multiply both numerator and denominator by some trial digit, e.g. 3, 4, or 5, until the numbers thus obtained are equal to the number of teeth on the gear-wheels actually available; the product of the trial number and the numerator (or lathe-screw constant) gives the gear for the spindle stud, whilst the result of multiplying the trial number and the denominator gives the lead-screw gear. Most up-to-date lathes obviate calculations by having a quick-change gear device incorporated, which merely involves the setting of one or more levers to positions shown by an index plate.

CHAPLETS (Foundrywork). Small pieces of metal used to provide additional support to cores which are not otherwise adequately supported. They are placed between the mould face and the core, and ensure that the required wall thickness is obtained in the casting.

CHARGE (Elec. Engineering). Term normally used in connexion with electrostatic phenomena, wherein a unit charge is defined as that charge which repels with a force of one dyne, an exactly similar charge placed one centimetre from it. One dyne is about $\frac{1}{27{,}000}$ of an ounce's weight. The word is also used as a verb to mean the act of imparting electricity to a body, as in charging a condenser, and also in connexion with accumulators to mean the conversion of electrical into chemical energy. See COULOMB'S LAW.

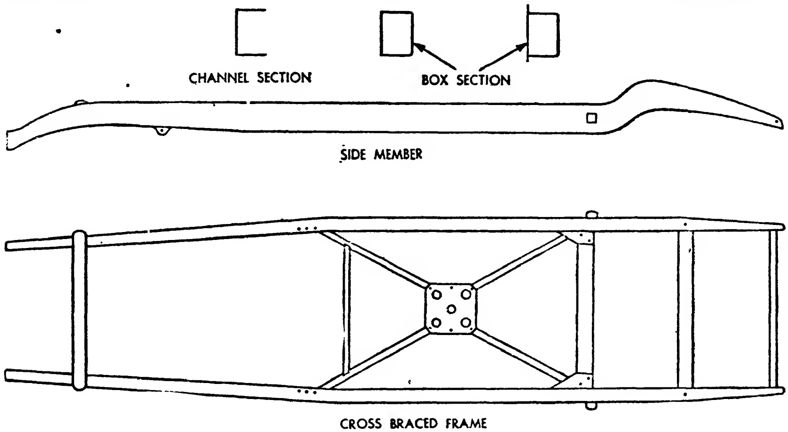
CHASE. A frame used in printing, made of wrought steel or cast-iron, which encloses the forme (q.v.). See also COMPOSING.

CHASSIS (Auto. Engineering). A term broadly applied to the chassis frame together with the engine, gear-box, axles and wheels, without the coachwork and auxiliary fittings, as



FEATURES OF A TYPICAL CHASSIS

Fig. 1. Complete chassis of a modern car as it appears before the body is fitted.



CHASSIS FRAME MEMBERS

Fig. 2. Diagram showing main structure of a chassis, with channel and box sections indicated. Lower part of the illustration depicts a complete cross-braced frame.

shown in Fig. 1. It is capable of being driven under its own power.

The main structure, or chassis frame (Fig. 2), is approximately rectangular in shape and consists of two side-members braced together by cross-members secured by rivets, bolts or welding. In general, the frame members are of channel or box section (Fig. 2) and are made up of steel pressings.

The cross-members of a motor vehicle are arranged to support part of the transmission system and control mechanism; the engine is mounted on suitably placed bearers while increased stability is given by angle brackets where side-members and cross-members join. For cars, the side-members of the frame are arched to obtain a low body position. Bearers, which are riveted or bolted to the side-members to support the springs are known as dumb-irons.

CHEEKS, see DORMER WINDOW.

CHEMICAL ANALYSIS. The process of finding out what elements or groups of elements are contained in a substance. Measuring weights and volumes further enables the chemist to state in what proportions these elements or groups are found. A very common method of analysis is to dissolve the substance in water, or in a mixture of water and an acid, and then to add a liquid which will bring down one of the metals in the form of a precipitated compound that can be dried and weighed. Thus, if a material is suspected of containing silver or lead, some hydrochloric acid is added to a solution of it; if silver or lead is present a white precipitate of silver chloride or lead chloride is formed. By the examination of the spectrum of a material, it is possible to determine with a good deal of accuracy both what elements it contains and the relative proportions of them. See SPECTRUM ANALYSIS.

CHEMICAL WARFARE. Warfare carried on by the so-called poison gases, most of which are liquids or solids that give off poisonous or irritating vapours. Some of these bodies irritate the lungs (phosgene, $COCl_2$), some the eyes, causing a flow of tears (chloroacetophenone, $C_6H_5COCH_2Cl$), others cause sneezing (diphenylchloroarsine, $(C_6H_5)_2AsCl$), while still others cause blisters (mustard gas, $ClCH_2CH_2SCH_2CH_2Cl$ and Lewisite, $ClCH{:}CHAsCl_2$, both liquids).

CHESTNUT. A wood found in Europe, and often used as a substitute

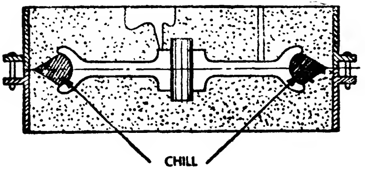
for oak in constructional and underground work, and joinery. It is similar to soft, plain oak, without rays, has many of the characteristics of oak, is durable, easily wrought and may be obtained in large sizes. See TIMBER.

CHILL. A piece of metal inserted in the face of a mould to produce rapid cooling of the molten metal at that particular spot, sometimes known in foundries as a "densener". Chills are employed for two distinct purposes: either to produce a hard surface on grey-iron castings, or to equalize the rate of cooling throughout the mould to prevent drawing due to shrinkage.

For example, if a relatively heavy boss is attached to the thin wall of a casting, solidification will take place first in the thin wall and in the more remote parts of the boss. The last parts to solidify will be the centre portion of the boss and the junction of the boss and wall.

Two results are possible: either internal shrinkage cavities will be formed, or the solidification of the central portion of the boss will cause external shrinkage, or drawing, at or near the junction of the two parts. This can be avoided by attaching a feeding head to the boss, but if this is inconvenient or impossible, chills may be used to hasten solidification of the boss. This will cause it to solidify before the remainder of the casting, and in this way proper feeding of the boss through the thin wall of the casting is made possible. See CHILL CASTING.

CHILL CASTING. An iron casting specially made so that some, or all, of its faces are intensely hard and white. For example, a cast-iron rope-pulley



Mould for rope pulley with chilled rim, effected by inserting a chill.

must have a hard rim to prevent wear and abrasion caused by grit picked up by the rope, but the bore must be soft and readily machinable. These hard surfaces are produced by inserting pieces of metal into the mould face as shown, so that rapid cooling of the molten metal is produced locally. The thickness of the hard surface is controlled by the size of the chills employed. See CHILL.

CHIMNEY BACK. The back wall of any fireplace opening. When situated in a party wall the chimney back must be at least 9 in. thick up to a height of 12 in. above the arch or lintel which covers the fireplace opening.

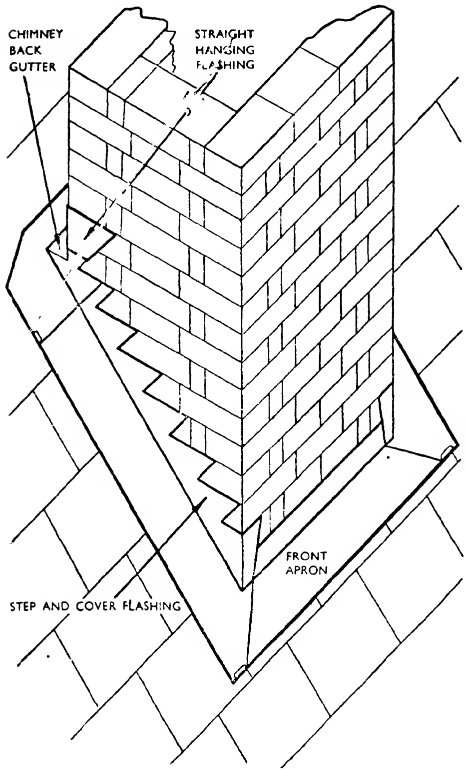
CHIMNEY BREAST. That part of the wall containing the flues and fireplace which does not rise above the roof. As a prevention against fire, under building by-laws no timber is permitted to be built into the brickwork of a chimney breast. To accommodate the flues, the chimney breasts of upper floors may be corbelled out from the face of the wall, provided that the amount of projection does not exceed the thickness of the wall from which it springs.

CHIMNEY JAMBS. The attached piers on each side of a fireplace opening. The width of the jambs is governed by the number of flues contained within the jamb. The minimum width is 9 in., but a 13½ in. minimum is usually adopted.

CHIMNEY STACK. That part of the wall which continues from the chimney breast and rises above the roof. It contains the flues leading from the fireplaces below, and should be continued to a minimum height of 3 ft. above the highest point of intersection with any part of the roof.

CHIMNEY WEATHERING. The waterproof joint between a brick-built chimney and the sloping roof through which it passes, usually made of sheet metal, either lead or zinc.

The illustration on the next page shows the method; an apron is fixed in front, the top edge being turned into a joint of the brickwork and the lower part bent to lie flat on



Weathering for a chimney consists of a sheet of lead, known as an apron, turned into a suitable horizontal joint in the brickwork and lying over the roofing slates.

the roof; flashing and soakers are used at the sides, while the back is weathered with a chimney-back gutter similar in section to a parapet gutter. See FLASHING, ROOFWORK, SOAKER and STEPPED FLASHING.

CHINA CLAY. The natural aluminium silicate formed by the disintegration of granite: a white, soft, dry powder used as an extender in combination with other pigments. In water paint it dries opaque, but in oil paint is fairly transparent, and may form the base for cheap lakes (q.v.). As an extender it gives ease in working and an improved grip upon the surface.

CHINESE BLUE. A pigment formed by the reaction of a solution of iron salts with ferro-cyanide solutions. It is a very strong stainer; in admixture with white it produces a more brilliant colour than Prussian or Antwerp blues. In common with these blues, contact with alkalis destroys its colour.

CHINESE RED, see CHROMIUM.

CHINESE WHITE, see ZINC WHITE.

CHINESE WOOD OIL, see TUNG OIL.

CHISEL. A cutting tool of steel, sharpened at one end. A variety of chisels, shown in Fig. 1, are used by the joiners but the *firmer* chisel is the general utility tool. The *bevelled-edge* chisel is used for more delicate work, or paring, as it cuts more easily, but it is not so strong. The handles are usually of beech or box, and the blade is fixed in the handle by a tang, or tapering end. A shoulder to the tang prevents it from driving too far into the handle, and a brass ferrule prevents the handle from splitting. These chisels may be obtained from $\frac{1}{16}$ to 2 in. wide. *Paring* chisels have long, bevelled-edges, and are not strong enough to stand the use of the mallet. *Socket* chisels, of which the handle fits into a conical socket, are used for heavy work.

Other types of chisel are: mortise, sash or pocket, drawer-lock, and swan-neck chisels. The *pocket* chisel has a wide, thin blade sharpened both sides, and is used for forming the pockets in sash and frame windows. The *swan-neck* chisel is used for removing the core of a mortise to receive a mortise lock.

Chisels used by bricklayers are round, hexagonal, or octagonal, and

are ground to a cutting edge and tempered. They are mainly used, with a hammer, for cutting chases or keys in brickwork and for removing old brickwork where additions are to be made. See Bolster.

Some of the commoner forms of cold chisel used by engineers and fitters for cutting metal are shown in the Fig. 2. At *A* is shown a *flat* chisel, the form used for general work, the cutting edge being either ground to a straight line or made slightly

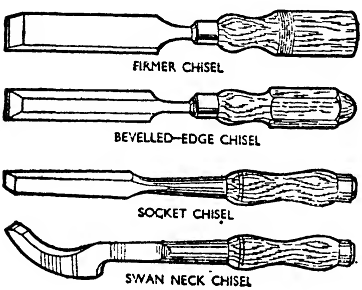
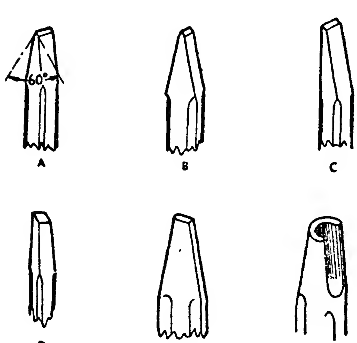


Fig. 1. (Above). Several types of chisel used by the joiner. **Fig. 2.** (Below). Cold chisels of widely differing shapes have numerous uses in mechanical-engineering operations.



convex. The latter form renders the corners less liable to break off. The angle included between the two cutting faces, as distinct from the main tapering portion of the chisel, should be fairly large, about 60 deg.; it may be increased if the metal to be chipped is hard or decreased if it is soft.

The *cross-cut* chisel *B* is chiefly employed for cutting grooves, etc.; it has a narrower cutting edge than the flat chisel, while the *side* chisel *C* has the cutting face on one side only, so that it can be used on surfaces which an ordinary flat chisel could not reach. It is also sometimes used for chipping slots, key-ways etc. At *D* is a *diamond-pointed* chisel, specially ground for chipping V-grooves or for squaring corners. The *grooving* chisel *E* is suitable for cutting oilways in bearings etc., and *F* is a *half-round* chisel or *gouge*, employed for chipping curved surfaces.

CHLORINE (Cl). Atomic no., 17; atomic wt., 35·457; a greenish-yellow, poisonous gas, m.p. −100·9 deg. C.; b.p. −34·5 deg. C. It is prepared from common salt or by the electrolysis of brine. Chlorine forms compounds with most of the other elements and is usually monovalent, but sometimes heptavalent. It forms oxides, Cl_2O, ClO_2, Cl_2O_6, and Cl_2O_7. It combines with hydrogen to form hydrochloric acid, HCl, from which a series of chlorides is made of which common salt, sodium chloride, NaCl, is the most familiar.

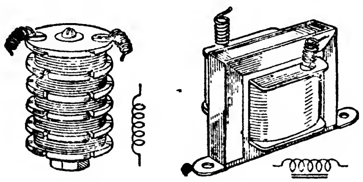
Ammonium chloride, NH_4Cl, is known as sal ammoniac. Chloride of lime, or bleaching powder, is made by passing chlorine over damp lime; it is not a true chloride, but a mixture of calcium chloride, with basic chlorides, calcium hydroxide, and other calcium compounds.

From chloric acid, $HClO_3$, are formed many chlorates, one of which, potassium chlorate, is largely used in medicine. Chloroform is a compound of carbon, hydrogen, and chlorine, with the formula $CHCl_3$. In very many of the compounds of carbon and hydrogen, chlorine can replace hydrogen; from benzene, for instance, is formed chlorobenzene, C_6H_5Cl, largely used as a solvent.

CHLOROPRENE (CH_2:CCl.CH:CH_2). A colourless liquid, immiscible with water and made by treating vinyl acetylene, CH_2:CH.C:CH, with

hydrochloric acid. It polymerizes slowly to a rubber-like solid and is used in the preparation of synthetic rubbers.

CHOKE. A winding which opposes, or tends to oppose, any change of current flowing through it. This characteristic is due to its inductance (q.v.) and, in fact, such windings are often more correctly termed inductances. Inductances, or reactors as



On the left in the above diagram is shown a typical high-frequency choke and on the right a low-frequency choke with iron core. Appropriate symbols used in circuit diagrams are given.

they are sometimes called, for radio purposes may be divided broadly into two classes; those dealing with high (*radio*) frequencies, and those employed for low (generally *audio*) frequencies. The former type usually have an air or dust-iron core while the latter are provided with laminated soft-iron cores.

CHOKING COIL, see INDUCTOR.

CHROMATOGRAPHIC ANALYSIS. A method of separating substances of very similar behaviour by virtue of the different rates at which they are adsorbed. A solution containing the substances is allowed to percolate through a column of adsorbent, often activated alumina, and the various substances are adsorbed in distinct bands, which are then separated.

CHROME. A group of pigments in which the metallic element chromium (q.v.) forms one of the constituents. The pigments possess considerable brilliance and good covering, or obscuring, power, and vary in colour from a primrose yellow to a bright red. The precipitation of chromes is shown in the accompanying diagram. When a solution of bichromate of potash is added to a solution of acetate of lead the normal deep chrome is precipitated.

For the paler varieties, sodium sulphate in solution is also added. The deeper tones are obtained by the conversion of the normal chromate into the basic chromate by boiling it with caustic soda.

All these are in the form of a dry, soft powder consisting wholly of insoluble lead compounds. These pigments are most brilliant when used in a water medium; in admixture with linseed oil the lighter colours tend to turn greenish and the darker ones are dulled.

In combination with Chinese, Prussian and Antwerp blues they are the source of many brilliant greens. Although these may be termed chrome greens they should not be confused with oxide of chromium, a dull green

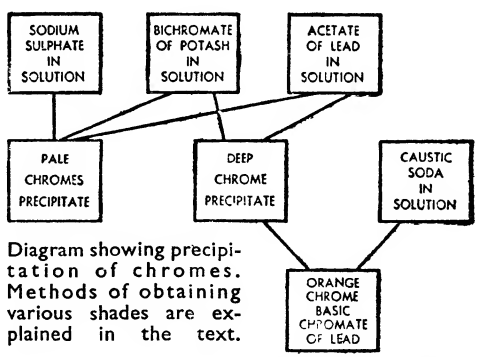


Diagram showing precipitation of chromes. Methods of obtaining various shades are explained in the text.

of uniform colour and different characteristics.

The basic chromate known as chrome red, is an excellent pigment for use as the priming coat on iron-work. All lead chromes are discoloured after having been in contact with sulphuretted hydrogen fumes.

The primrose-coloured chrome is made by substituting a zinc for a

lead salt and is not affected by these fumes.

CHROME YELLOW, see CHROMIUM.

CHROMIC OXIDE, see CHROMIUM.

CHROMIUM (Cr). Atomic no., 24; atomic wt., 52·01; a hard, malleable, silvery-blue metal, very resistant to corrosion; density 7·14, m.p. 1805 deg. C., b.p. 2,220 deg. C. Chemically it resembles molybdenum, tungsten, and uranium; it is hexavalent. It alloys with iron and steel, to which it gives hardness and freedom from corrosion. It forms four oxides, chromous oxide, CrO, chromic oxide, Cr_2O_3, chromium dioxide, CrO_2, and chromium trioxide, CrO_3. Chromium plating is used to prevent the corrosion of steel.

Chromium trioxide is a powerful oxidizing agent, and forms salts and chromates, analagous to the sulphates. Potassium dichromate, $K_2Cr_2O_7$, is used in electric batteries, in photography, in the dyeing industry, in tanning, as a bactericide and for other purposes. Lead chromate, $PbCrO_4$, is an important yellow pigment known as chrome yellow; basic lead chromate, Pb_2CrO_5, is an orange-red pigment known also as orange chrome or Chinese red.

CHROMIUM DIOXIDE, see CHROMIUM.

CHROMIUM TRIOXIDE, see CHROMIUM.

CHROMIUM PLATING. An electro-plating process which has been practised commercially for only the past twenty years, but is now very widely used. There are several unique features in the process. First, much higher currents are used than are usual in most plating processes (100 to 200 amp. per sq. ft.). Second, the metal may be deposited with a mirror-like finish without making additions to the solution, provided that a suitable current density and temperature are used. Third, chromic acid, which is the main constituent of the solution, is carried into the atmosphere by the gases evolved during the plating and may seriously injure the health of the operatives, thus necessitating a powerful exhaust system over the vat.

There is only one solution in comme cial use, and this, essentially, is the same as the one originally suggested: Chromic acid, 40 oz. per gallon, Sulphuric acid, 0·4 oz. per gallon. Variations in concentration are sometimes met with, but no solution fundamentally different from the above is in commercial use. It is usual to deposit chromium over nickel which must be of a ductile variety, such as that deposited from baths containing chlorides. Deposits of chromium cause peeling of other types of nickel coating. See ELECTRO-DEPOSITION.

CHROMOUS OXIDE, see CHROMIUM.

CHUCK. A tool used chiefly for holding work to be machined on various types of lathe; also on other types of machine tool, e.g. drilling machines. For lathe work it affords the most convenient method of gripping the workpiece; chucks are especially useful if the diameter of the work is large or the length of the piece is not too great.

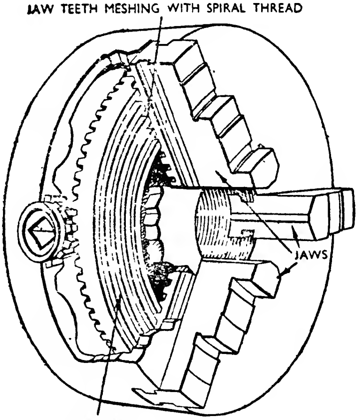


Fig. 1. Universal, or self-centring, chuck used for holding workpiece.

The chuck itself is a circular steel body with movable jaws which slide

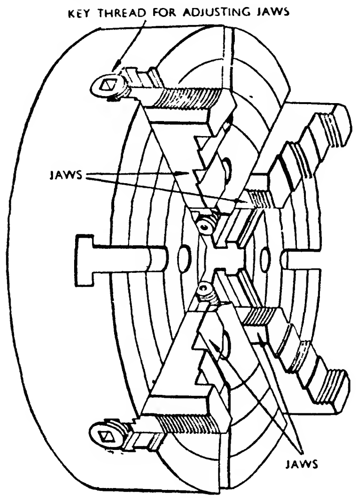


Fig. 2. In a chuck of the independent type, the jaws can be moved separately. Above diagram shows four-jaw variety.

towards, or away from, the centre; the body is made to screw on to the machine spindle in place of the face-plate. Each jaw is stepped to enable work of various ranges of diameter to be held, the faces of the steps being furnished with grooves which improve the grip and prevent the workpiece from slipping.

In most cases the jaws are reversible; if all the jaws move together when worked by the long key or spanner provided, the chuck is known as the universal or self-centring type illustrated in Fig. 1. In the other principal variety, the independent chuck, the jaws can be moved separately. Three or four jaws shown in Fig. 2 are most commonly used.

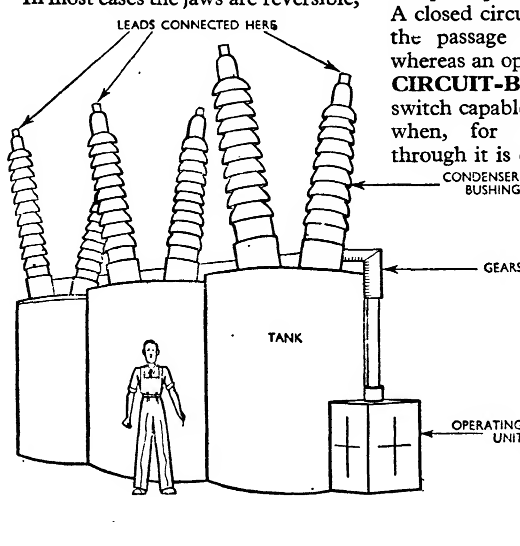
The independent chuck is necessary where irregularly shaped pieces have to be held while some part of them is being turned; when circular work has to be gripped, the universal type is more convenient. Power-operated chucks, using oil under pressure or compressed air, are now in wide use. Another variety is the magnetic chuck, but this is confined chiefly to light work.

CIMENT FONDU, see CEMENT.

CIRCLIP. A split steel ring designed to expand or contract into an annular groove, used to keep a given component in position. An example of its use is the method, employed in motor engineering, of locating a floating type gudgeon pin in a piston. The boss on which the pin fits has an annular groove at its two extremes in which two circlips fit. The gudgeon pin is positioned between the two rings to prevent excessive end movement.

CIRCUIT (Elec. Engineering). A complete path for an electric current. A closed circuit is one which permits the passage of an electric current whereas an open circuit prevents it.

CIRCUIT-BREAKER. An electrical switch capable of automatic operation when, for example, the current through it is excessive. Small circuit-breakers are usually tripped, i.e., opened, by the direct action of a trip coil, but in larger sizes relays are almost always



Bank of three single-phase circuit-breakers for voltages up to about 150 kV. Each tank contains one double-break switch under oil. The figure of a man is included to show the size.

interposed. The diagram shows a large modern circuit-breaker. See RELAY, SWITCH, and TRIP COIL.

CIRCULAR PITCH. In gearing, the distance measured along the circumference of the pitch circle between two successive gear teeth.

$$\text{Thus: circular pitch} = \frac{\text{P.C.D.} \times 3{\cdot}1416}{\text{No. of teeth}}$$

where P.C.D. denotes pitch-circle diameter. This method of describing the spacing of teeth is usually reserved for cast gear-wheels, in which the teeth are not subsequently cut or finished in any way. In particular it is confined to larger pitches. If the teeth are to be cut by a machine, the *diametral pitch* (q.v.) is more often used, especially where the value of the diametral pitch is greater than one.

CISSING. The contractile action within a paint, enamel or varnish film which causes the applied material to gather together in globules instead of spreading out easily and evenly. It is caused by the undercoating being too oily or too hard-dry. When this tendency is present it indicates that the undercoat may be greasy from exposure or that it has not been sufficiently granulated by cutting-down with an abrasive.

CISTERN. A container for water-storage purposes. The domestic cistern should be at a point high enough to ensure sufficient head or pressure to give ample flow at all taps, and should be of sufficient capacity to serve both hot- and cold-water systems.

The Metropolitan Water Board stipulate a minimum of 80-gallon storage where a hot-water system is

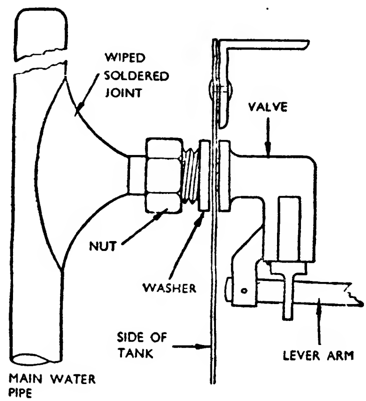


Fig. 2. Ball-valve connexion to a cistern should be rigidly made to the tank itself with appropriate nuts and washers, a wiped-soldered joint being made to the main pipe.

installed. The catalogue capacity of a cistern is the capacity of that cistern when filled to the brim, a level never reached in practice, owing to the fact that the ball valve (q.v.) automatically shuts off the supply about 4 in. below.

Cisterns are usually made of riveted or welded plates, galvanized after assembly, but those of the larger type can be assembled and painted on the site. They should be protected from frost by a wooden casing filled with sawdust or some other insulating material, and should be fitted with a dust-proof cover as shown in Fig. 1. The ball-valve connexion to a cistern should consist of a brass cap and lining, soldered to the lead pipe by means of a wiped-soldered joint through the side of the cistern. The method is

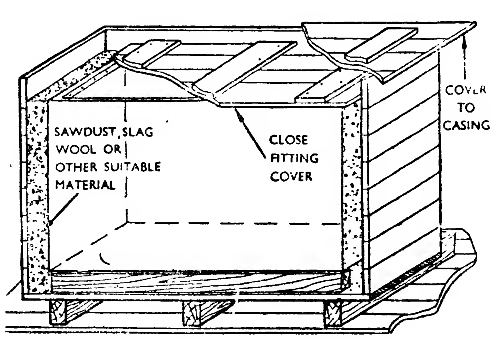


Fig. 1. Method of protecting cistern for cold-water supply from frost by means of a casing of sawdust, slag wool or other suitable material.

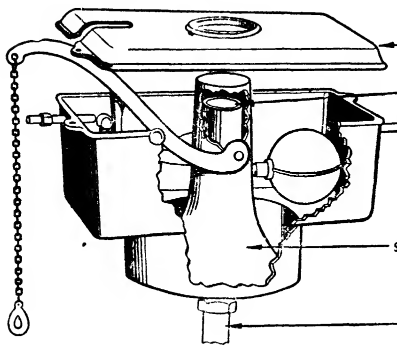


Fig. 3. Flushing cistern of valveless or water-waste preventing type. Flushing is initiated when the siphon dome is raised and lowered, thus forcing a quantity of water into the flush pipe and causing siphonic action to begin.

illustrated in Fig. 2. In no case should the ball valve be slung over the top edge of the cistern to hang unsupported over the water.

Flushing cisterns (q.v.) should be of the waste-preventing or valveless type. This means that water cannot flow down the flush pipe except when a flush is being properly delivered. Siphonic action is used to set up the flush, the method employed varying with the type of cistern. Fig. 3 shows the type most commonly fitted; the bell, or siphon dome, when lifted and dropped, throws a quantity of water over into the flush pipe to commence siphonic action. The siphon dome and discharge pipe should be corrosion resisting, and the cistern must be provided with an efficient overflow pipe, which also acts as a warning pipe. The automatic flushing cistern used in public conveniences is regulated to discharge the flush water at intervals without attention.

CITRIC ACID. An acid occurring in the juice of the lemon and some other fruits. It is largely used in the preparation of cooling drinks, such as lemonade, and is manufactured artificially by fermenting sugar by various moulds.

CIVIL ENGINEERING. The science of designing and constructing works for use by, and for the benefit of, the general public. This includes the laying of roads and railways, and the construction of bridges, canals, docks and drainage systems etc.

With the purpose of protecting the interests of those engaged in this class of work, the Institute of Civil Engineers was founded, a royal charter being granted in 1828 in which the profession was defined as "the art of directing the great sources of power in Nature for the use and convenience of man."

In the United States, the American Society of Civil Engineers was founded in 1852 with similar aims.

CLACK VALVE. In mechanical engineering, a valve used to permit water to pass from a fuel pump to the boiler of a steam engine.

CLAD METAL. A composite material consisting of an ingot or billet of two metals or alloys, the one having special properties, such as corosion resistance, being used to cover a base metal. The billet may be subsequently rolled into sheet form.

CLAMP (Carpentry). A device consisting of two parallel rods or bars, and equipped with screws which can be tightened down to hold securely any work placed in it. A clamp is used to hold together parts of a wooden article while a glued joint dries, or to locate two pieces during constructional work.

CLAPPER BOX (Mech. Engineering). An attachment to the saddle of a planing machine used to carry a block on which the tool is clamped. The purpose of a clapper box is to enable the tool to be swung clear of the work on the return-stroke of the planing-machine table.

CLARAIN, see COAL.

CLASS A. A method of operating power amplifiers so that the anode current of a valve flows continuously throughout the cycle and is, in waveform, a faithful reproduction of the voltage that is applied to the grid.

CLASS B. An efficient system of power amplification in which the anode current of a valve is zero for almost half a cycle. The elimination of even harmonic distortion resulting from this method of operation is accomplished by using two valves in a push-pull arrangement.

CLASS C. A system of power amplification, confined to radio-frequency amplifiers with tuned loads, in which anode current flows for considerably less than half a cycle. Such a system has a relatively high anode-efficiency and is largely used in radio transmitters.

CLAY. Moist, finely divided plastic masses of hydrated silicates of alumina, some of them containing impurities such as considerable quantities of silica, calcium carbonate, gypsum, oxide of iron and small quantities of alkalis and other minerals.

Beds of clay of different qualities and geological ages are found in many countries.

Some of them seem to be these beds formed by the disintegration of granite and other volcanic rocks; others are probably formed by the disintegration of older clays, for clay is almost indestructible by natural agencies.

The particles of the clay may vary in size, but on the average they are about 0·05 mm. in diameter. Some clays contain quantities of decayed vegetable matter.

Clays are burned to make bricks, the colour of which depends largely on the amount of iron they contain and the temperature of the firing. Some bricks are white, some yellow, some red, some blue and others almost black.

China clay or kaolin is employed in the manufacture of china and porcelain; it consists of minute crystals, which are supposed to be of kaolinite. Such pure clays have an average composition of about 46 per cent silica, 40 per cent alumina and 14 per cent water.

Refractory clays possess a high resistance to heat and contain a large proportion of silica. They are used to make furnace linings and furnace bricks.

CLEARANCE VOLUME. The volume above the piston in the cylinder of an internal-combustion engine when the piston is at the inner, or top, dead-centre position. It is the volume into which air or gas is compressed when the valves are closed as the piston makes its compression stroke.

The volume displaced by the piston is known as the swept volume, thus the clearance volume is equal to total cylinder capacity less swept volume; while the compression ratio of the cylinder is equal to the total volume (with the piston at bottom dead-centre) divided by the clearance volume. See INTERNAL-COMBUSTION ENGINE.

CLOCK GAUGE. A gauge or measuring instrument with a dial and pointer, also often known as dial gauges. Various patterns are available for providing highly accurate information as to comparative variations in the dimensions or surfaces of a machined article.

Though reading to thousandths, or even ten-thousandths, of an inch on the dial, clock gauges do not actually provide absolute measurements to such a degree of accuracy, but they do afford, within those limits, indications of parallelism, or the lack of it, in the workpiece.

The general working principle is to arrange for a contact point to be placed so as to touch the machined article, and for the spindle attached to the contact point to operate a train of gears which in turn rotate the needle over the dial. The gears are designed to magnify the movement of the contact piece a predetermined number of times to correspond with the graduations on the dial.

Such gauges are used for a variety of purposes—for testing surfaces for flatness, for setting workpieces in lathes, milling machines etc., or for setting articles parallel with a marking-off table. Usually the dial is so arranged that it can be rotated through any angle in order to bring

the zero reading under the needle. Zero reading is then taken as corresponding to the specified measurement. Plus or minus divergencies can then be read directly from the dial, without it being necessary to add or subtract an initial reading each time.

CLOSE ANNEALING. The process of heating cold-worked steel sheet to a temperature of about 650 deg. C., which is fairly close to, but below, the critical range, soaking and slowly cooling.

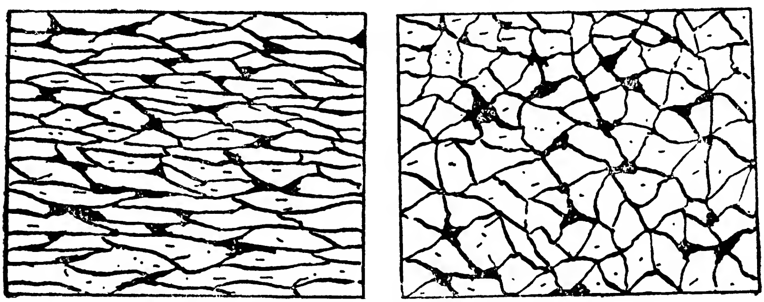
The strained ferrite (iron) then recrystallizes, softness and ductility are restored, and the steel is in a condition suitable for further rolling or forming. The process is also known as box annealing (q.v.) or pot annealing.

In box annealing, steel sheets are packed with cast-iron borings in sealed boxes, and a reducing gas is passed in during cooling to exclude air and prevent scaling. Bell type furnaces are also used in large-scale sheet production, the charge being in a sealed container, over which a radiant tube furnace is lowered. The inner cover surrounding the sheet contains a reducing gas.

CLOSED CIRCUIT, see CIRCUIT.

CLOSER. A portion of a brick, which, when placed in position, gives a correct start in fixing the brickwork bond on the face of a wall. It is usually placed next to a quoin header or in the centre of a length of wall to complete its length between fixed dimensions. A *Queen Closer* is obtained by halving the width of a brick throughout its length from, say, 4½ in. to 2¼ in. A *King Closer* is a brick reduced to 2¼ in. on one header face only, the other remaining the full standard width.

In masonry, a closer brick is the last stone to be placed in a course to fill a gap. See BOND, BRICKS and BRICKWORK.



MILD-STEEL CRYSTALLINE FORMATIONS

Diagram showing (left) crystalline structure of cold-worked mild steel (elongated crystals, work-hardened condition), and (right) mild steel close annealed after heavy cold-working (equiaxial crystals, ductility restored) as explained in the text.

CLUTCH. A device by which the power or torque of an engine can

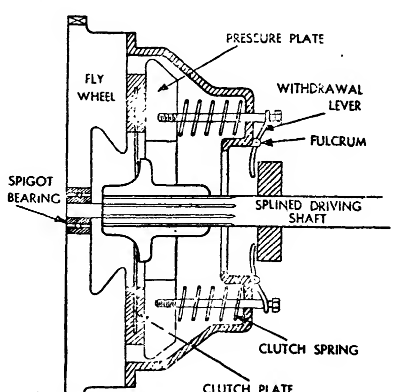


Fig. 1. Three main parts of a single-plate clutch—flywheel, driven plate and pressure, or outer, plate—are clearly shown in above illustration.

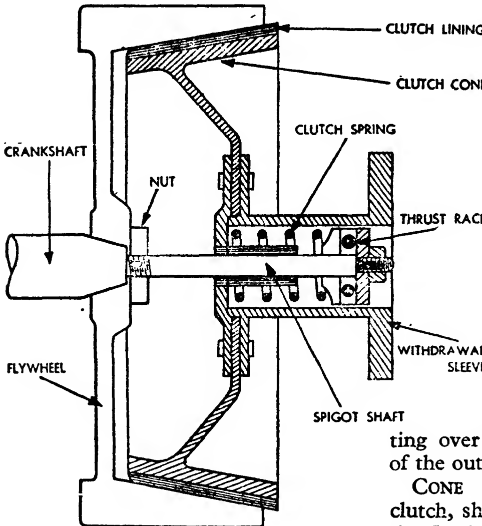


Fig. 2. In cone clutches, a cone, lined with friction material, grips the interior of a suitably shaped flywheel.

be transmitted or not, as desired. Clutches are necessary on motor vehicles in order to bring them to a standstill without stopping the engine, to enable the turning effort to be applied to the road wheels gradually and smoothly and to release the drive when gear-changing. The clutch is situated between the engine and the gearbox and depends for its action on two frictional surfaces being brought together by an ever-increasing pressure as a foot-operated lever is released. On most vehicles, the flywheel forms one part of the clutch; the other part, which is free when the clutch pedal is depressed, slides on a central shaft in or out of engagement as required. Clutches are of three general types: single-plate cone, and multiple-plate.

Single-Plate Clutch. This clutch (Fig. 1) consists of three principal members: flywheel, driven plate and outer plate. The flywheel has around its outer surface a deep rim, machined perfectly flat, and at right-angles to it are a number of studs on which this smooth-faced outer plate is free to slide. The driven plate is faced on both sides with friction fabric and, at its centre, is secured to the clutch shaft by splines. It is made to rotate by being squeezed between the flywheel and outer plate. Pressure is applied by a number of compression springs fitting over the flywheel studs on top of the outer plate.

Cone Clutch. This type of clutch, shown in Fig. 2. incorporates the flywheel, the interior of which is shaped to receive a movable cone. This cone is lined on its outer surface with leather or composition material to provide the necessary grip. The cone assembly, which is bushed, is carried on a spigot shaft and drives the primary shaft of the gearbox. A spiral spring exerts a pressure on the cone under normal running conditions, holding it firmly in contact with the flywheel. The withdrawal mechanism separates the cone from the flywheel by forcing the cone assembly against the tension of the spring, and

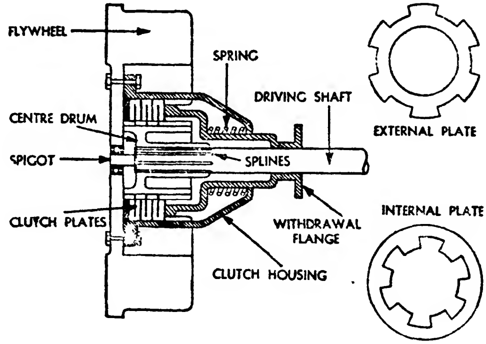
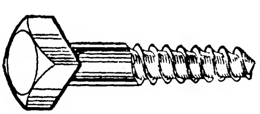


Fig. 3. Plates in a multi-plate clutch are keyed alternately to the driving and driven members.

enables the driven and driving members to rotate at different speeds, dependent on the amount of friction and load. Thus one member may be rotating while the other is stationary.

Multiple-Plate Clutch. As the name implies, a number of plates are used, keyed alternately to the driving and driven members as shown in Fig. 3. The driving member is in the form of a drum, secured to the flywheel and rotating with it and splined on its inner circumference to receive projections on the outer edges of the driving plates. The driven member is also a drum splined on its outer circumference and secured to the clutch shaft. The splines correspond to the form of the internal projections on the driven plates. The necessary pressure is applied by a spring exerting a force on a plate which presses and holds the plates tightly together when the clutch is in operation. Clutches of this type are designed to work in oil.

COACH SCREW. A wood screw with a square head. It is seen on



Coach screws are widely used in heavy-timber constructional work.

only one side of the work, and when turned with a spanner draws itself into the wood up to the head. See Bolt.

COAL. The remains of trees, ferns and other plants that once grew on land or marshes close to the sea and were afterwards covered by sand, mud, and sea-water or estuarine water. This process was in some districts repeated many times, and finally thick deposits of clay, sandstone and other rocks were laid down on the decaying vegetable matter.

The action of bacteria, of warmth or heat, and of pressure extending for thousands of years, drove off much of the oxygen and hydrogen from the carbohydrates that formed the vegetable matter, until a black carbonaceous mass was left, sometimes an inch, sometimes several feet, thick. This coal varies in properties, containing about 40 per cent to 8 per cent of volatile matter.

The most important varieties of coal are anthracite and bituminous coals. Anthracite contains very little volatile matter, and gives off very little gas on heating. The bituminous coals give off more gas on heating, and burn with brighter flames than anthracite.

Bituminous coals, however, consist of four different kinds of material; fusain, a dull, fibrous, friable material making thin veins in the coal; vitrain, which is brittle and lustrous; clarain, usually present in a larger proportion than the two kinds previously mentioned, and showing under the microscope spores and other vegetable cells; and durain, which is not so lustrous or brittle as vitrain, but hard and dull in appearance and often found in thick seams.

When bituminous coals are heated in a retort, the ordinary domestic gas is driven off and coke is left in the retort. Coke consists of carbon mixed with a mineral ash, partly consisting of silica and oxide of iron. This ash may amount to 10 per cent or more by weight of the coke.

Anthracite burns without smoke and is specially designed for indoor domestic stoves. Coking coals are used for making coke for smelting purposes; they should contain little sulphur and phosphorus. The gas driven off from coke-ovens is collected, freed from benzene and toluene which are valuable by-products, and in some districts is mixed with the town gas and in others is burned to afford heat and power in the vicinity of the coke-ovens.

When coal is heated to make town gas, the benzene, toluene and sulphur compounds are removed from the gas, and the large quantity of tar produced is distilled, producing benzene, toluene, phenol, ammonia, cresols, cyanogen compounds, and so on, from which many hundreds of aniline dyes

and valuable drugs are manufactured. See BENZENE.

COAL GAS, see FUELS.

COAL-TAR DYESTUFFS. Soluble compounds of carbon, hydrogen, and other elements; they are prepared from various substances obtained in the distillation of coal-tar. Among such substances are benzene, C_6H_6, phenol, C_6H_5OH, aniline, $C_6H_5NH_2$, naphthalene, $C_{10}H_8$, and anthracene, $C_{14}H_{10}$. Coal-tar pigments are insoluble in water and are compounds of coal-tar dyestuffs with a metallic oxide, or a mixture of metallic oxides, e.g. aluminium oxide, tin oxide, and barium oxide.

COARSE STUFF. A mixture of sand, lime and hair, used as a base for all plasterwork. The hair should be thoroughly mixed with the other ingredients so that it gives the resultant material a fibrous texture. It is good practice to use hair with all cement mixtures in ordinary building work, as it helps to prevent cracks brought about by expansion and contraction stresses due to atmospheric or other conditions.

CO-AXIAL CABLE. An electric cable in the form of a tube containing a central conductor. Such cables are designed to have the lowest possible losses and may use air insulation with the conductor supported only at intervals along its length. Cables of this type are needed for the transmission of very high frequencies such as are employed in television. See TRANSMISSION LINE.

COBALT (Co). Atomic no. 27; atomic wt. 58·94; a silvery-white metal obtained from silver ores in Ontario and copper ores in New Caledonia; density 8·8; m.p. 1,480 deg. C.; b.p. 3,185 deg. C. It resembles nickel and iron in its chemical properties, and is readily polished. It is a constituent of some high-speed steels and of super-magnet steels. Cobalt is usually divalent, forming the oxide CoO, a chloride $CoCl_2$, and a sulphate, $CoSO_4$, but trivalent compounds are known.

A mixed oxide of cobalt and aluminium is a permanent blue pigment used in the colouring of pottery. A blue glass, called smalt, is formed by fusing cobalt arsenate with sand and potassium carbonates. Solutions of cobalt chloride, $CoCl_2$, in water are pink, but turn blue on the addition of hydrochloric acid. Cobalt is magnetic at temperatures below about 1,100 deg. C.

COCKPIT. The opening in the fuselage, or body, of an aircraft, usually for the pilot but also for passengers, where there is no enclosed cabin. The term "cockpit" is also applied to the open steering well of small yachts and motor-boats.

COD. A core made in the mould by means of the pattern, and not in a separate core box. This type of pattern is said to leave its own core.

COEFFICIENT. A quantity denoting the rate of change of any property; a ratio expressed in non-dimensional terms, i.e. a coefficient is not measured in physical units such as the pound.

In aircraft, for instance, the drag coefficient of an aerofoil indicates the ratio between the actual drag of an aerofoil and the drag which would be experienced by completely stopping the airflow over an area equal to half that of the aerofoil.

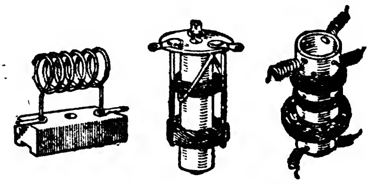
COERCIVE FORCE. The negative magnetizing force needed to reduce to zero the magnetism remaining in a body after it has been magnetized. A negative magnetizing force may be produced by reversing the current in a magnetizing coil. See MAGNETIC HYSTERESIS.

COGGED JOINT, see JOINTS.

COGGING, see JOINTS.

COIL (Radio). Any winding in a receiver but generally one associated with a tuned circuit. Tuning coils are of infinite variety, ranging from short-wave types consisting of a few turns of self-supporting wire to long-wave windings of many turns wound in layers or banks.

Certain radio-frequency coils often contain dust-iron cores. Owing to its permeability, such a core gives the required inductance with fewer turns and may, with correct design, reduce



On the left in above diagram is shown a typical short-wave coil of the air-core self-supporting type; in the centre, a small receiving coil comprising medium-wave and long-wave windings; and right, an example of several bank-wound coils on one former.

the overall losses. This improves selectivity and magnification.

The efficiency or "goodness" of a coil is known as its "Q" factor, and is the ratio of its reactance to its effective resistance:

$$Q = \frac{2\pi fL}{R},$$

where f is the frequency in cycles per second, L the inductance in henrys, and R the effective resistance in ohms.

COILER. In metallurgy, a drum around which sheet metal is coiled on emerging from the final stand of the hot-finishing on to the runout table. The material is down-coiled hot before passing to cold reducton and finishing where the coil formation is maintained; it is then ejected by an air-operated coil push-off, arranged with the necessary pinch-and-guide rollers. See CONTINUOUS ROLLING.

COINING PRESS. A special type of press used to form designs on thick materials, e.g., coins, medallions, etc. by cold pressing. The machines need considerable power and toggle or knuckle joint presses, ranging in weight from 3 to 75 tons, are used.

The action of the press is to give a squeeze as opposed to a blow, for this purpose slow movement enables the metal to flow under the pressure of the punch, and to form sharp edges or curves with clear die-markings, whereas an equal force in the form of a blow could cause the metal to crack.

Coining presses are usually of the single-action adjustable-ram type. Brittle metals cannot be coined cold.

COKE. A solid fuel produced by distilling the volatile matter from coal (q.v.). In metallurgy, for use in the cupola (q.v.), or furnace, coke should be hard, strong and dense, since it has to support, without being crushed, the entire weight of the cupola charges. It should contain a minimum of 85 per cent fixed carbon and not more than 3 per cent moisture, 1·1 per cent volatile matter, 10 per cent ash and 1 per cent sulphur.

COKES (Tinplate). Grades of hot-dipped tinplate with relatively thin coatings, 0·00009 in. thickness or thereabouts, which are normally used

COKES: AVERAGE THICKNESS OF COATING: (in.)	NAME	
	U.K.	U.S.A.
0·00008	—	Standard Coke plate
0·00006 to 0·00008	Cokes	—
0·00009	—	Best Coke Plate
0·00009 to 0·00011	Best Cokes	—
0·000105	—	Canners Special
0·00011 to 0·00014	Common Charcoals	—
0·000135 to 0·00014	—	Charcoal 1A
		„ 2A
0·000195 to 0·00021	Charcoals and Best Charcoals	„ 3A „ 4A
0·00042	—	Premier Charcoals 5A
Up to 0·001	Heavily coated charcoals Special charcoals	— Not made

for container and closure manufacture. The term *charcoal tinplate* or *charcoals* describes the grades of tinplate having tin coatings relatively thicker than cokes. In the early days of the industry the better grades of tinplate were made from charcoal iron and the cheaper grades from coke iron. It is from this that the terms were derived, but they now indicate the range of tin-coating thickness only and do not imply any special method of manufacture or any special steel quality. The exact range of coating thickness associated with the term varies in different countries and different works, but the accompanying table serves as a guide to general practice.

COLD CATHODE, see GAS-FILLED VALVE.

COLD CHISEL, see CHISEL.

COLD-ENAMEL PROCESS. A printing process consisting of coating a smooth metal surface with a light-sensitized solution in which is dispersed shellac or some other resinous colloid, natural or synthetic; drying by evaporation of the solvent; hardening, preferably by light exposure through a stencil, generally of a photographic nature, which renders the exposed sections relatively insoluble and durable developing the unhardened film in spirit; etching the consequently exposed metal; and finally, dispersing the light-hardened film which now covers the raised printing areas.

COLD-WORK. Any deformation which can be imparted to metals at or near room temperature. For the purpose of this definition any small local heating of machine parts may be ignored, as, for example, roll-contour control in skin-passing or cold-rolling.

When thin metal or sheet is being rolled, however, it is sometimes necessary to keep passing the metal through the rolls after the usual lower temperature limit has been passed, and while this is not true of cold work, the effect on the metal is the same.

The physical properties disturbed by cold-working are to some extent restorable by annealing (q.v.), the most noticeable effect being recrystallization, but to impart a desired structure to any metal the variables associated with cold-working, heat treatment, and ageing must be known and controlled as accurately as possible.

COLLATING. The process, in bookbinding, of checking the gathered sections of a book to ensure that they are complete and in the correct sequence. To facilitate this check a signature is printed on the first page of each section. See BOOKBINDING and SIGNATURES.

COLLODION, see CELLULOSE.

COLLOIDS (Chemistry). A term originally applied to substances which could not pass through a dialysis membrane, as opposed to crystalloids, which could pass the membrane. It is now possible to prepare many substances, not previously regarded as colloids, in colloidal form, and a substance is defined as being in the colloidal state if its particles, of size between 1 and 100 mμ are dispersed in a continuous medium.

There is no sharp demarcation between colloids and crystalloids. The particles in colloidal solutions are larger and are visible when a beam of light shines on the solution. This is known as the Tyndall effect. Colloids can be subdivided into hydrophobic sols, which are easily coagulated by adding salts, hydrophilic sols, which are not easily coagulated, and gels, which are partially coagulated, jelly-like solutions.

COLLOIDS (Painting). Gluey substances which possess the characteristics of a jelly; smooth and slippery to the touch they adhere to materials with which they make contact and are not affected in this respect by excessive dilution. When solidified by the natural evaporation of the diluent they stick fast to the surface upon which they have been spread in a film and, therefore, form satisfactory media for some types of painting. Glue, gelatin, starch, flour paste and natural gums are used for this purpose and also for fastening paper and other materials to plaster and

similar surfaces. See PAPERHANGINGS and GILDING.

COLLOTYPE. A photomechanical printing process of the planographic group. Collotype prints resemble photographs more closely than prints by any other of the graphic processes. No screen is used, but magnification of a collotype print reveals a natural reticulation or a crepe-like formation.

The collotype printing image is produced from a continuous-tone photographic negative of a soft character or low contrast. The base plate, of thick glass or thin flexible material, such as zinc, aluminium, celluloid etc., is given a grain or tooth to serve as an anchorage for the films. A key substratum is formed with a solution of sodium silicate, which is dried by heat and cooled before coating with a sufficiently generous solution of bichromated gelatine to form a thick film when dry. This film is also dried by heat, and the rate of heating and the temperature largely influence the quality of the reticulation.

The negative is placed in position on the sensitized plate, and exposure is made preferably in either daylight or mercury-vapour light. The plate is then developed in a bath of running water until the yellow of the bichromate is completely removed. It is during this stage that the film reticulates. The plate is drained and allowed to dry spontaneously in a dust-free atmosphere. The image now appears in slight relief.

To prepare the plate for printing, the image is covered with a mixture of glycerine and water, a process known as *etching*. This solution is absorbed by the gelatin, and causes an amount of swelling related to the amount of light which has affected the film. The parts of the film which were exposed through the clearest parts of the negative are hardest and absorb least solution but attract most ink during printing. Conversely, the opaque parts of the negative preserve the moisture-absorbing property of the film, and ink is rejected; intermediate tones attract and repel ink and moisture in proportion to the amount of hardening they have received. The plate is now ready for printing.

The collotype printing machine is similar to the direct flatbed litho machine with certain differences, the chief of which is that the damping system is replaced by a second inking unit. Damping is done by hand, and the gelatin holds enough moisture to enable a series of prints to be taken. As the moisture is used up the inking becomes stronger—hence the difficulty of maintaining uniform results.

Slow production and short life of the printing plate limit the process to short editions, but the exquisite charm of the best work ensures collotype printing a continued place in modern processes for de luxe editions. Medical and scientific plates and art reproductions are features, and used with lithography as a reinforcing medium for coloured subjects, all kinds of work are possible. Thick glass plates are used as the base for flatbed machine printing, but the most modern development uses flexible aluminium plates in conjunction with rotary offset machines and humidity control, resulting in long runs and faster speeds. Several thousand prints can be taken from a single etching, and sizes up to 60 by 40 in. are used.

COLLOTYPE INKS. A printing ink similar to the highest grade of lithographic offset ink; highly concentrated owing to the very thin film of ink which is used in the printing process. Driers are seldom used, except in blacks. See COLLOTYPE.

COLOUR CODE. A code adopted by radio manufacturers for identification of the values of certain radio components. The system, generally applicable to various standard components and connexions thereto, is much used to indicate the ohmic value of resistors. See RESISTANCE COLOUR CODE.

COLOUR-CONTROL SYSTEM. A method of distinguishing the size-ranges of tool-room gauges etc. by means of distinctive colours. The

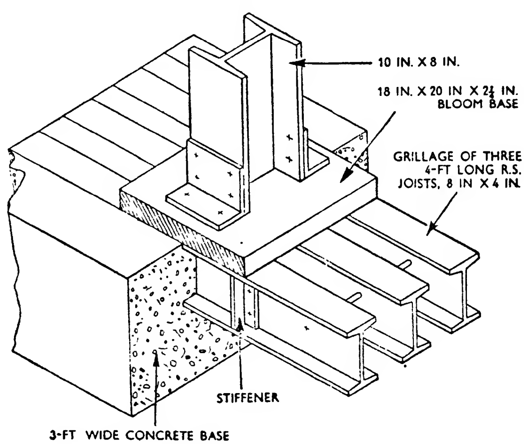
scheme was originally devised to aid Sudanese workmen, who had difficulty in understanding the European system of expressing limits and tolerances. It was soon realized, however, that a colour-control scheme could with advantage be adopted in Europe, both as a means of saving time and as a preventive measure against mistakes.

For classifying gauges, a group colour—yellow, for example—is first chosen for colouring the shanks of all gauges between, say $1\frac{3}{4}$ and 2 in. diameter. Above the latter size another group colour is adopted, up to, say, $2\frac{1}{4}$ in., and so on. For the subdivision of each group grooves are machined on the gauge shanks and are afterwards given characteristic colours according to the various steps. A further subdivision of each step into different series is indicated on the shank by a groove of a third colour.

The system has been recently extended to cover the control of machine tool operations, various combinations of colours being employed as quick guides to the various positions of the handles used to obtain different spindle speeds on lathes, boring and milling machines, radial drills etc. It virtually does away with the speed plate, which, in many machines, has reached a high degree of complexity. Small "windows" are provided in which the various colours appear on the machine.

It is claimed that the substitution of combinations of colours for speed plates indicating the positions of levers instantly shows whether the machine is set correctly for a certain speed and that, as with the application of colour control to gauges, it affords a universal language whereby machines embodying this system can be used anywhere in the world. To guard against possible mistakes through colour blindness, each colour is always associated with a particular shape, e.g. green is characteristically shown in a circle, red in a square, yellow in a triangle and so on.

COLUMN FOUNDATION. A bed of concrete placed below the base of a column. Its function is to spread the loads carried by the column over a wider area than is covered by the column base. Column foundations are necessary, unless the ground on which the building stands is rock.



In buildings erected on soft ground, foundations of concrete must be laid at the bases of columns in order to spread the load over a greater area.

The area of the concrete foundation varies according to the type of soil, but must always be sufficient to distribute the loads on the column evenly over an area of ground large enough to support them. Further, the thickness of the concrete bed must be sufficient to prevent any fracture of the concrete.

COOLIBAH, see EUCALYPTUS.

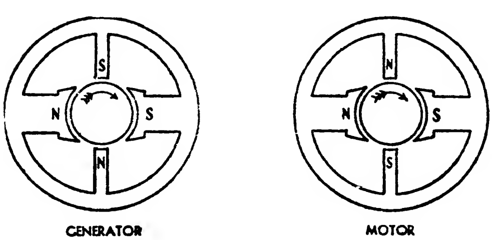
COMBINATION MACHINES. Printing machines which carry out two or more processes in a simultaneous operation. They may also perform other functions such as perforating, folding, punching, slitting, creasing or any combination of these. Examples of combination machines

include the letterpress or gravure unit for aniline printing in several colours, also the gravure litho and letterpress in any combination. The letterpress may be used for numbering in any desired order, ruling both across and down the sheet, and perforating and folding.

COMBUSTION. The combination of a substance with oxygen accompanied by the evolution of heat and light.

COMBUSTION CHAMBER. A chamber designed for the burning of an air/fuel mixture. In an internal-combustion engine the combustion chamber is that space within the cylinder head and above the piston, when at top dead-centre, into which the gases are compressed before ignition. The combustion chamber of a fire-box is the space above the grate, either part of the fire-box or a specially shaped chamber connected to it by a flue, in which the gases are given extra turbulence and further combustion is obtained.

COMMUTATING POLE. A pole situated between two main poles of an electrical machine as shown in the diagram. The thin poles are the commutating poles, whereas the thick ones are the main poles. Commutating poles induce an e.m.f. into armature coils, while they are short-circuited by the brushes, in order to assist the reversal of the current in the coils. This is known as commutation. Synonyms: Interpole, Compole.



Commutating poles enable D.C. motors and generators to run at all loads without sparking. The diagram shows the relations between magnetic polarities of main and commutating poles.

COMMUTATOR. The portion of an electrical machine which enables connexion to be made from an external circuit to successive points in a rotating winding. It usually consists of a number of copper bars, insulated from one another, and built up into a cylinder upon which the brushes slide. The term is occasionally used to mean a current-reversing device, such as a two-pole two-way switch. See BRUSH.

COMMUTATOR MOTOR. An electrical induction motor modified by the fitting of a commutator (q.v.) and, usually, additional windings, for the purpose of power-factor improvement, or speed control, or both. See MOTOR.

COMPASS. A magnetic instrument which indicates the magnetic north. It may have either a fixed card on which are marked the various points, north, south, east, west etc., with a pivoted magnetized needle which swings above the card as the instrument is turned, or the card itself may be magnetized so that the "N" (north) always points to the magnetic north.

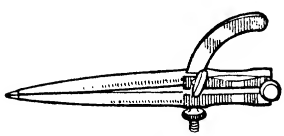
The former type is used mainly in pocket compasses, while the card type is the well-known mariner's compass; it has the advantage that the "lubber's line", a line indicating the fore-and-aft line of the ship, always indicates the magnetic course, whereas with the needle type the whole compass has to be turned until the "N" is under the north-seeking pole of the pointer before a reading can be taken.

The compass card is usually divided into 32 points, allowing 8 intermediate readings between the cardinal points already mentioned, each of which has a name, i.e. north, north-by-east, north-north-east, north-east-by-north etc.

These points are further divided into quarters, and in most cases in small craft, where there may be violent motion, that is the most

accurate reading that can be taken. Another method, however, is to divide the card into 360 deg. and to discard the named points: thus, reading from 0 to 360 deg., the course east, magnetic, would be 90 deg.; south, magnetic, would be 180 deg. and so on. Compasses are used for all forms of surveying besides navigation.

COMPASSES. Instruments for marking-out small circles and arcs, stepping-off distances, and for scribing skirting to floors, mouldings to



Compasses of the type that are used in carpentry for a variety of purposes.

walls etc. A light, adjustable pair is illustrated. A screw is provided to keep the leg fixed in position on the wing, and a milled nut on a threaded rod to make fine adjustments. For describing large circular arcs, or for stepping-off large distances a *trammel* is used in place of compasses. The wood rods, carrying the pins, may be of any length. Trammel pins, or heads, are fixed in position on the rod by milled nuts. One of the heads has a socket to hold a pencil for marking surfaces.

COMPOLE, see COMMUTATING POLE.

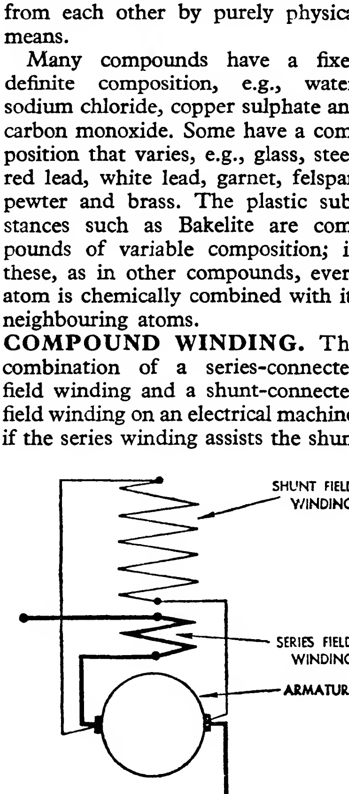
COMPOSING (Printing). The operations necessary to produce all the constituents in a composite page or sheet of printed matter contained in a forme in a condition suitable for printing on the letterpress machine. These operations include the setting and correct spacing of lines of type to specified measure either by hand or by machine, placing the spacing material between the lines, building-up borders, and locking-up the whole in a steel frame, or chase, (q.v.). See also FORME.

COMPOSITE WALL. A wall built with bricks and faced with stone or other material. The height of the stone course should be arranged to coincide with the total height of several brick courses, thus forming a bond with the brickwork and producing a solid mass. When concrete walls are faced with stone, it is usual to omit the bond and to anchor the stone slabs to the concrete.

COMPOUND. A substance produced by the chemical combination of different elements. The physical and chemical properties are usually quite different from those of its component elements. The components of a compound cannot in general be separated from each other by purely physical means.

Many compounds have a fixed definite composition, e.g., water, sodium chloride, copper sulphate and carbon monoxide. Some have a composition that varies, e.g., glass, steel, red lead, white lead, garnet, felspar, pewter and brass. The plastic substances such as Bakelite are compounds of variable composition; in these, as in other compounds, every atom is chemically combined with its neighbouring atoms.

COMPOUND WINDING. The combination of a series-connected field winding and a shunt-connected field winding on an electrical machine; if the series winding assists the shunt



Compound-wound machines have characteristics intermediate between those of shunt and series machines. The arrangement shown is known as short-shunt, as opposed to long-shunt in which the shunt winding is across both armature and series windings.

winding, the machine is cumulatively compounded; in the opposite case it is differentially compounded. Compound windings are fitted to modify the speed characteristic of a motor, or the voltage characteristic of a generator or rotary convertor. The diagram on the previous page shows a compound-wound direct-current machine with a short-shunt arrangement.

COMPRESSIBLE FLOW. A term used to describe the changes occurring under certain conditions in the density and temperature of the air flowing round an aircraft. These changes are caused by local variations in the speed of the air.

At flight speeds up to 0·3 or 0·4 of the speed of sound the local variations of the speed of the air are not accompanied by any appreciable changes in density. The flow is then said to be *incompressible*.

At higher speeds, however, the variations in velocity are accompanied by changes in density and temperature and the air approximately obeys the adiabatic gas law, i.e. it does not gain or lose heat. This behaviour of air is known as *compressible* flow, and gives rise to several compressibility phenomena.

The most important is the shock stall. This occurs when the local velocity over a part of the aircraft reaches a value equal to the speed of sound. A shock stall is accompanied by a rapid increase of drag and, when it occurs on the wing, by a marked loss of lift. See INCOMPRESSIBLE FLOW and MACH NUMBER.

COMPRESSION (Building), see STRESS.

COMPRESSION-IGNITION ENGINE. An internal-combustion engine which requires no electric spark to ignite the charge in the cylinder. Liquid fuel is injected, in the form of a very fine spray by a nozzle, into the combustion chamber where it is ignited by the heat of compression of the air with which the chamber is already charged. The compression-ignition (C.I.) engine is similar in general design to the petrol engine, but it is built on more robust lines to withstand the effects of higher compression ratios. In a four-stroke C.I. engine the sequence of operations is as follows.

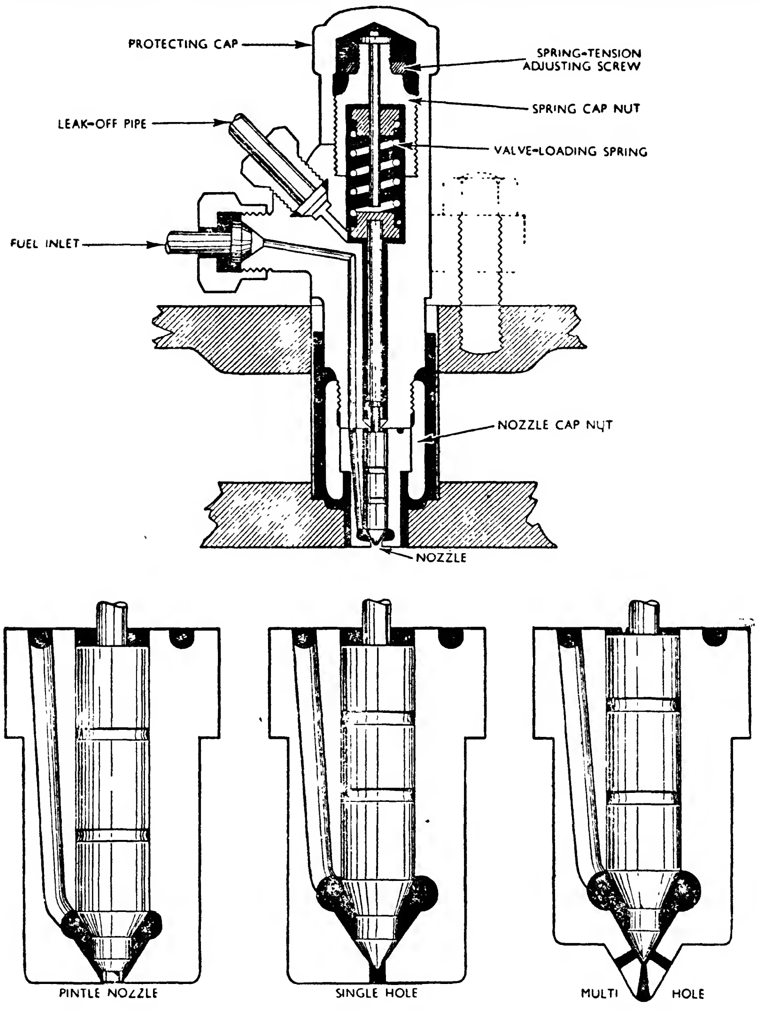
Induction Stroke: as the piston descends on the induction stroke the depression created draws a charge of air into the cylinder through the inlet valve, which opens just before top dead-centre.

Compression stroke: when the piston has passed bottom dead-centre and is commencing its upward travel, the inlet valve closes and further movement of the piston compresses the air charge in the cylinder to such an extent that its temperature rises very rapidly. At top dead-centre the temperature is high enough to ignite a charge of fuel oil injected into the cylinder at this precise moment.

Power Stroke: the burning of the air-fuel charge brings about rapid expansion of the gases which push the piston downwards and produce the power stroke.

Exhaust Stroke: before the piston has reached bottom dead-centre the exhaust valve opens and, as the piston once more ascends, the burnt gases are forced out through the exhaust pipes and silencer. Again just after top dead-centre the exhaust valve closes, the inlet valve opens before T.D.C. and the cycle re-commences. Compression: to raise the temperature of the air trapped in the cylinder on the compression stroke sufficiently to ignite the fuel charge, a compression ratio of between 14 and 20 to 1 is required. Owing to this high compression, the fuel oil must be injected at a very high pressure to penetrate the dense volume of air and, therefore, a special type of injection pump is used. A minute quantity of fuel is forced through a nozzle drilled with very tiny holes inserted into the combustion chamber.

The fuel is raised from the main tank by a pump, and is carried by a pipe line, passing through a number of filters, to the injection system. An injection pump is made in units suitable for 1, 2, 3, 4 or 6 cylinder engines. In addition to pumping fuel



FUEL INJECTOR AND NOZZLES

Diagram showing a C.A.V. fuel injector as used on compression-ignition engines. The lower part of the illustration shows three variations of nozzle design.

into the cylinders it incorporates intricate mechanism for controlling the quantity of fuel injected, thus providing a means of controlling engine speed by varying the fuel supply.

The injector itself consists of a main body carrying a nozzle at one end. The nozzle is normally kept closed by means of a spring-loaded needle. When the pressure from the injection pump is sufficiently high the needle valve is lifted off its seating, and injection of the fuel oil takes place either through very fine holes, or through an annular space. The operating pressure can be adjusted by altering the initial compression of the

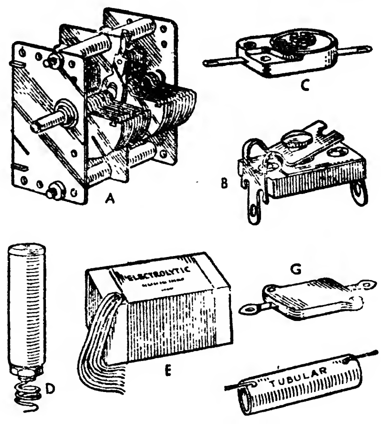
control spring by screwing down the adjusting nut. See INTERNAL-COMBUSTION ENGINE.

COMPRESSION RATIO. In automobile engineering, the ratio of the total volume of mixture held in the cylinder, with the piston at the outer, or bottom, dead-centre position, to the volume contained when the piston has made its compression stroke. The volume displaced by a complete stroke of the piston is called the swept volume, and that contained in the combustion chamber is known as the clearance volume; thus the compression ratio of a cylinder is the ratio of the sum of the swept and clearance volumes to the clearance volume.

In aeronautical engineering, however, the term compression ratio is used also to represent the ratio between the pressure of the air delivered to the engine by a supercharger and the pressure of the air entering the supercharger, and is usually referred to as the pressure ratio. In aircraft engines, a rise in compression ratio may be used to produce higher boost pressure at a given altitude or to increase the altitude to which a certain boost pressure can be maintained.

CONCRETE. A mixture of hard, coarse and solid substances such as broken brick, broken stones, gravel, shingle and sand bound together by cement. The former constituents are known as the aggregate and the latter as the matrix. The correct proportioning of concrete depends upon the stresses to which it is likely to be subjected. For ordinary foundation work a mixture of six parts large aggregate, two parts sand and one part Portland cement will produce a good concrete. The exact proportion of water to cement is difficult to specify, but the ideal quantity is such that it will produce a very stiff workable concrete. Concrete mixing is best carried out in machines if large quantities are required.

CONDENSER. A piece of electrical apparatus, now usually known as a capacitor, capable of receiving and maintaining an electric charge and having the property of capacitance (q.v.). A simple condenser consists of two metal plates separated by a dielectric (q.v.).



Various types of condenser widely used in radio. As explained in the text they have numerous uses; those at D, E, F and G are the fixed-value type.

In radio, condensers are employed for many purposes, including the following:

(1) In conjunction with a coil for tuning purposes.
(2) Providing a "reservoir" from which a steady current supply may be drawn.
(3) Providing a low impedance route by which alternating currents can by-pass higher impedance branches.
(4) Passing on an A.C. signal from stage to stage, while isolating D.C. circuits from each other.

For (1) condensers are usually either variable air-spaced types or of the pre-set trimmer variety. In the diagram, A shows two variable condensers on a common spindle, both rotors operating simultaneously. Such an assembly is known as a *ganged* condenser. Trimmer condensers permit fine adjustment of capacitance or the tuning of circuits which seldom need adjustment. They usually consist of small plates of spring metal separated by thin sheets of insulating material which serve as the main dielectric

(sketch *B*). The capacitance is varied by a screw which determines the separation between the plates. Sketch *C* illustrates a trimming condenser in which capitance is varied by altering the overlap between semi-circular plates which are a fixed distance apart.

For uses under (2), current "smoothing", electrolytic condensers are often employed; illustration *D* represents an aqueous, or wet, type and sketch *E* a dry type. These condensers provide a large capacitance in a small space. In the wet type, one plate of the condenser consists of a sheet or foil of aluminium, a molecular thickness of oxide becomes the dielectric, while the electrolyte itself is the other plate. In the dry type, which is basically similar, the electrolyte, instead of being free liquid, is held in suspension in paper or linen.

CONDENSER (Mech. Engineering). Steam condensers may be of either the jet or the surface type. In the *jet* condenser, a jet of cold water is introduced into the vacuum chamber with the steam; this type is used where there is a good supply of cold water.

The *surface* condenser consists of a system of tubes within a container, the cooling water circulating either through or around the tubes. Both types of steam condenser are fitted with a pump to maintain the vacuum within the condenser and are used mainly on large compound steam engines or turbines.

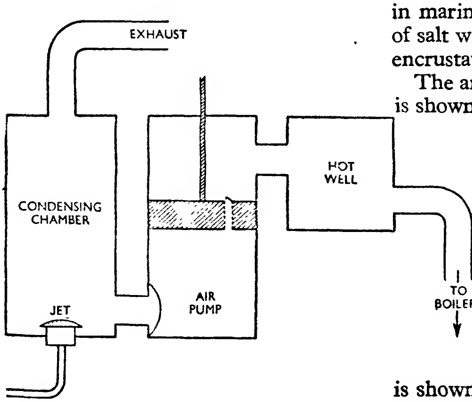


Fig. 1. Diagram showing component parts of a typical jet condenser.

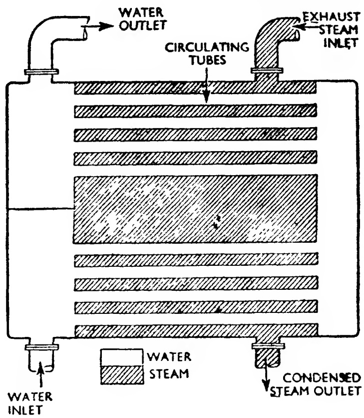


Fig. 2. Surface condensers such as that illustrated here are widely used in conjunction with marine engines.

The use of a condenser increases the thermal efficiency of a power plant by lowering the final temperature at which the steam is exhausted, i.e. the heat range is slightly increased, consequently increasing the pressure range and resulting in economy of steam. The great advantage of a condenser, however, lies in the fact that the boiler water can be used over and over again, an important point in marine installations where the use of salt water is impracticable owing to encrustation.

The arrangement of a jet condenser is shown at Fig. 1. The exhaust steam from the engine is condensed on meeting the jet of cold water in the condensing chamber, the resultant air and water being removed by means of the air pump and passed into a hot well. From here the water is returned to the boiler to be regenerated into steam. A surface condenser is shown in Fig. 2. This type consists of a cylindrical or other suitably shaped container enclosing a large number of thin circulating tubes of

brass, through which a constant stream of cooling water is forced by means of a circulating pump. The exhaust steam enters at the top of the container and comes in contact with the large surface area presented by the cold tubes, by which it is condensed. The condensation is removed by an air pump from the bottom of the condenser in the same way as in the jet condenser. In ocean-going ships, sea water is used for condenser cooling purposes, and is the stream of water which may often be seen gushing from a port in the vessel's hull.

CONDENSER MICROPHONE, see MICROPHONE.

CONDUCTANCE. Symbol, G. In direct-current circuits it is the reciprocal of electrical resistance. Thus a resistance of 2 ohms corresponds to a conductance of ½ mho. In alternating-current circuits, conductance is given by resistance divided by the square of the impedance. See IMPEDANCE, MHO and REACTANCE.

CONDUCTION. The transmission of heat from one part of a substance to another, the energy being passed from molecule to molecule.

In electrical engineering the term is widely used to denote the passage of a current by means of an electron drift. See CONDUCTIVITY (Elec. Engineering).

CONDUCTIVITY (Elec. Engineering). The electrical conductance between opposite faces of a unit cube of a material at a specified temperature.

It is the reciprocal of resistivity. See CONDUCTANCE.

CONDUCTIVITY (Heat). The ability of a substance to permit heat to flow through it.

It is very often spoken of as thermal conductivity. The coefficient of thermal conduction of a substance is the quantity of heat which flows in one second across unit area of a slab of the substance of unit thickness when there is a difference of one degree in the temperatures of the faces of the slab.

CONE CLUTCH, see CLUTCH.

CONE PULLEY. A device fixed to the driving shaft of a machine to form

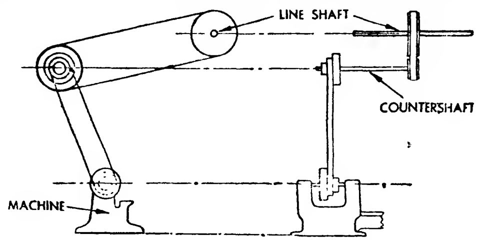


Diagram showing two views of cone-pulley assembly. On the right may be seen the arrangement of two "stepped" pulleys so fixed as to be facing opposite directions.

a simple means of providing a range of working speeds. A cone pulley is usually found on machine tools driven from line shafts rather than on machines with individual or group drives. As shown in the illustration, the pulley, instead of having a purely conical surface, is made so as to have a number of stepped diameters, sometimes as few as two or as many as five, and another exactly similar pulley is mounted the opposite way round on the countershaft, speed changes being obtained by shifting the belt from one diameter to another.

The difference in diameter from one pair of "steps" to another is usually made the same for shafts which are a fair distance apart. In such cases it can be assumed that the belt embraces about one-half of the circumference of each of the two steps on which it is running. If the shaft centres are near together, the belt will make a large angle with the centre line through the core centres; in such instances, or when the difference between the largest and smallest steps of the core is comparatively great, satisfactory running will not be obtained by providing equal increments between the steps.

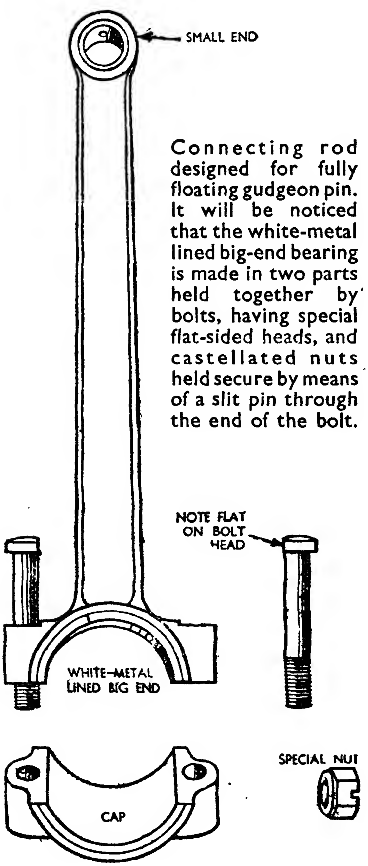
The length of the belt must then be taken into account, as a different length will be needed for running on the middle steps from that required

for running on the smallest and largest steps.

CONJUGATE FOCUS, see Focus.

CONNECTING ROD. That part of an engine which connects the piston with the crank; the link between the reciprocating motion of the piston and the rotary motion of the crank. Connecting rods are of various types according to the type of engine but are usually made of an alloy giving lightness consistent with strength. See Steam Engine.

In internal-combustion engines, particularly those of automobiles, the connecting rod is tubular or of H section, tapering towards one end; the piston is secured to this end, known as the small-end, by means of the gudgeon or wrist pin, which allows the rod to swing freely and enables the other end, or big-end, to follow the path of the crank pin as it rotates. The small-end is bored, and in some cases bushed, to receive the gudgeon pin.



Connecting rod designed for fully floating gudgeon pin. It will be noticed that the white-metal lined big-end bearing is made in two parts held together by bolts, having special flat-sided heads, and castellated nuts held secure by means of a slit pin through the end of the bolt.

The big-end is secured to the crank pin by a bearing which grips the connecting rod firmly enough to prevent up-and-down movement while allowing the pin to rotate. Owing to the formation of the crank-shaft, a divided white-metal bearing, as shown in the illustration, is used. The crank end of the connecting rod is shaped to receive one semi-circular half of the bearing, the other half being held in position by a cap. The cap and connecting rod are held together by bolts, and the bearing is prevented from moving round in its housing by dowel pegs, or inserts, between the two bearing halves.

CONSEQUENT POLE. One of two magnetic poles having the same polarity, which are situated adjacent to each other. For example, a permanent magnet might have a north pole at each end and two south poles together in the middle.

CONSERVATION OF ENERGY. Energy may be converted from one form to another, but it cannot be created or destroyed. A law to this effect was enunciated by Helmholtz in 1847 as: "In all processes occurring in an isolated system, the energy of the system remains constant."

CONSERVATION OF MATTER. Although recent work has shown that in certain circumstances radiation (a form of energy) is accompanied by a very small loss in mass, it is probable that mass and energy considered together can be neither created nor destroyed. This theory is known as the Law of Conservation of Matter.

CONSERVATOR. An auxiliary oil tank connected to the main oil tank of an electrical transformer to reduce the amount of oil which is in contact with the air.

CONTACT-BREAKER. A mechanically operated switch for intercepting current flow in petrol-

engine ignition systems. It has two metal contacts, or points, made of platinum alloy or tungsten-iridium. The points are normally held together by spring pressure and are separated by the action of a cam. It is essential that the points be kept perfectly clean and free from pitting, and that they meet squarely. They are cleaned or refaced by rubbing a small abrasive stone over their contact surface. See BATTERY-AND-COIL IGNITION and MAGNETO.

CONTACTOR. A power-operated electric switch, which may be worked electrically, pneumatically, or mechanically. It is normally used where frequent operation is required, as in the control gear of an electric train. See SWITCH.

CONTINUOUS ROLLING. A method of rolling steel in which the metal is finished in coils. This differs from the older, but still widely used, principle of two-high rolling, wherein the sheet sizes are maintained throughout from the bar-cutting stage. For clarity it is now customary to refer to material up to 24 in. wide as strip, and to describe all material over that width as continuous-sheet. It is also usual to classify continuous-mills by means of the optimum economical rolling width possible—54 in., 96 in. etc.

Plants making use of the continuous process have all their machinery designed in conformity. The successive stages from the open hearth are ingot, slab-rolling, roughing, hot-finishing, cold-finishing, skin-passing and shearing to size, with appropriate heat treatments as necessary. Sheets of thicker gauge material may be by-passed at the end of the hot-finishing, sheared to size, annealed and processed. At this point also it is possible to shear sheets to size for subsequent finishing in the cross-rolling mill, for obtaining greater widths than the normal plant can give.

On delivery to the blooming mill (q.v.), the ingot is rolled-down into slab thickness and sheared to length. The slabs may be either stacked to cool, when surface imperfections can be chipped out, or charged hot into the slab furnace. In the roughing-train of mills, the process is not truly continuous, as the material leaves each stand before passing on rolling tables to the next. Scale-breakers are inserted in this train, usually at the beginning and end of the roughing-train, scale being removed by high-pressure water spray. The hot-finishing process is truly continuous, the material being in all stands, four, five or six, simultaneously. After being down-coiled hot, the sheet coils are successively pickled, cold-reduced and delivered to the cut-up lines, where they are side-trimmed, roller-levelled, and sheared. If tinplate gauges have been rolled, the cold-work sequence is: cold reduction, electrolytic cleaning, annealing, skin-passing and, finally, shearing to size with preliminary sorting.

The advantages of rolling by the continuous method are: cleanliness of the metal surface, economy in production because of the enormous output which can be achieved, and the close metallurgical control which can be exercised at every stage. See COILER, FINISHING-TRAIN, FLYING SHEAR, FOUR-HIGH MILL, RECORDING PYROMETER, ROLLER LEVELLER, ROLLER TABLE, ROUGHING-TRAIN, SCALE BREAKER, SCREWDOWN, SKIN-PASS MILL, SLAB FURNACE, STRETCHER LEVELLER, TWO-HIGH MILL, and VERTICAL EDGING ROLLS.

CONTINUOUS-WAVE TRANSMISSION. Radio transmission in which waves of constant amplitude and frequency are radiated, there being no low-frequency modulation. For signalling, the intelligence is conveyed by emitting *dot* and *dash* bursts and is inaudible (except as a series of "clicks") in a receiver unless a local oscillator is employed to produce a beat frequency (q.v.).

CONTOUR CONTROL. Regulation of the shape of the rolls used in sheet-metal rolling processes. It is not possible to use straight barrels for the rolls, as accumulating heat from the actual work, skin friction, and heat from the necks distort their contour,

thereby increasing the possibility of roll breakage or of producing material of uneven gauge. When cold, the work-rolls are, therefore, given an amount of concavity dependent upon the width of the barrel and the control media to be used subsequently, in order to allow for such expansion.

The maintenance of accurate roll-contour governs not only the gauge accuracy of finished material, but also to some extent the surface appearance, as strip or sheet should not follow the top roll excessively. It is not customary to turn roughing or breaking-down rolls with great accuracy, although to some extent the shape imparted to the piece in these stands governs the subsequent treatment.

CONTRACTION OF CASTINGS. The change in dimensions that occurs in cooling a casting from the solidification temperature down to normal temperature. This contraction is allowed for by the pattern maker, who makes his pattern oversize by an amount depending on the metal being cast. Typical contraction allowances are: Cast-iron: $\frac{1}{10}$ in. to $\frac{5}{32}$ in. per ft. Steel: $\frac{3}{16}$ in. to $\frac{1}{4}$ in. per ft. Gunmetal: $\frac{1}{8}$ in. to $\frac{3}{16}$ in. per ft. Aluminium Alloys: $\frac{5}{32}$ in. per ft. Moulds, and especially cores, must not be rammed so hard and robust that they refuse to contract with the casting. Certain metals are so weak when hot that any resistance in the mould will crack the casting. In such cases, the casting must be knocked out of the mould as soon as it has solidified. See SHRINKAGE.

CONTROL COLUMN. A stick or column by means of which the pilot of an aircraft controls the attitude of flight. There are two forms: (1) the joystick, which is mounted on a universal joint at the lower end and moves forwards, backwards or sideways; and (2) the pivot type, which moves only in a fore and aft direction and has a wheel mounted at the top.

Sideways movement of the joystick type moves the ailerons, and controls the banking movement; it is moved to the left for a bank to the left, and vice versa. Forward or backward movement moves the elevators, and controls the diving or climbing angle, forward for a dive and backward for a climb. Fore and aft movement of the pivot type similarly controls the diving or climbing angle, but the wheel controls the ailerons, and is turned anticlockwise for a bank to the left, and vice versa.

CONTROLLER (Elec. Engineering). A device for controlling the operation of an electric motor. The controller may be left continuously in any one of several positions, so giving a number of alternative motor speeds, and it often serves also as a starter (q.v.). A starter may be left only in the "full-on" position.

CONTROL SURFACE. A movable portion of an aircraft's wing or tail, used to control the machine's attitude during flight. Conventional control surfaces comprise ailerons, rudder and elevators. They are usually actuated by means of cables running over pulleys and connected to the control column and rudder bar, although push-rods are in some cases used.

The control system may incorporate some degree of differential action. The differential applied to elevators and rudder is such that a given movement of the control column or rudder bar near the extreme end of the range causes a larger deflection of the control surfaces than does the same amount of column movement near the neutral position. This gives the pilot greater leverage over the small movements of the control surfaces used at high speeds without reducing the total movement of such surfaces required at lower speeds. See AILERON.

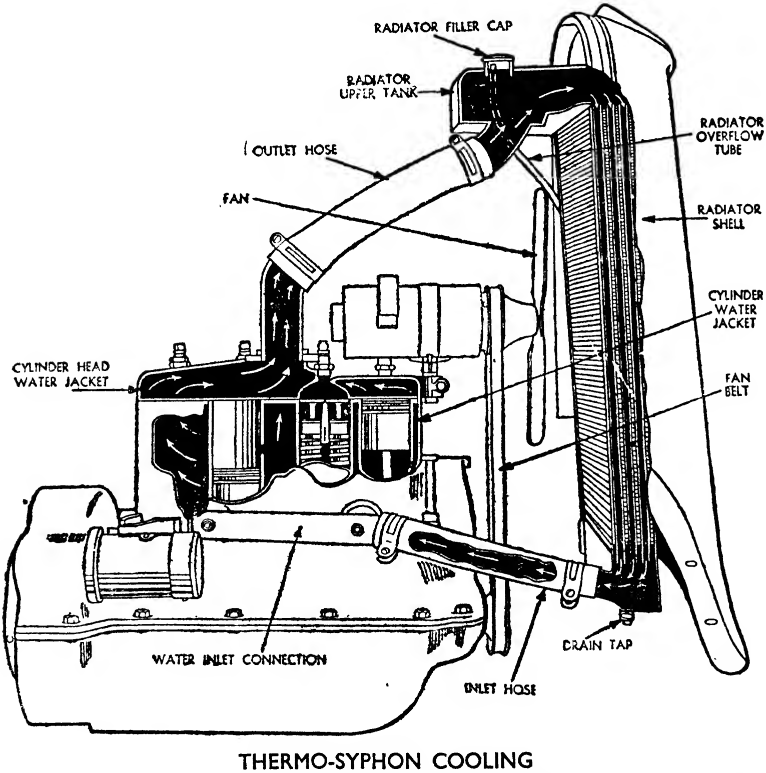
CONVECTION CURRENT. The movement of air or particles of a fluid under the action of heat. When the water in a boiler is heated each particle in contact with the boiler plates expands. A given fixed volume of water thus weighs less and is forced upward by the cooler, and therefore heavier, water which takes its place. This process continues until the whole of the water is in circulation, a principle which underlies all hot-water systems (q.v.) based on natural

circulation. The same principle applies to currents of air, warm air rising to make way for cooler air below it.

CONVERSION CONDUCTANCE. An expression for the efficiency, or "goodness", of a frequency-changer valve. It is the ratio of current at the intermediate frequency in the anode circuit to the signal voltage at the grid; it is expressed in microamps per volt or in micromhos.

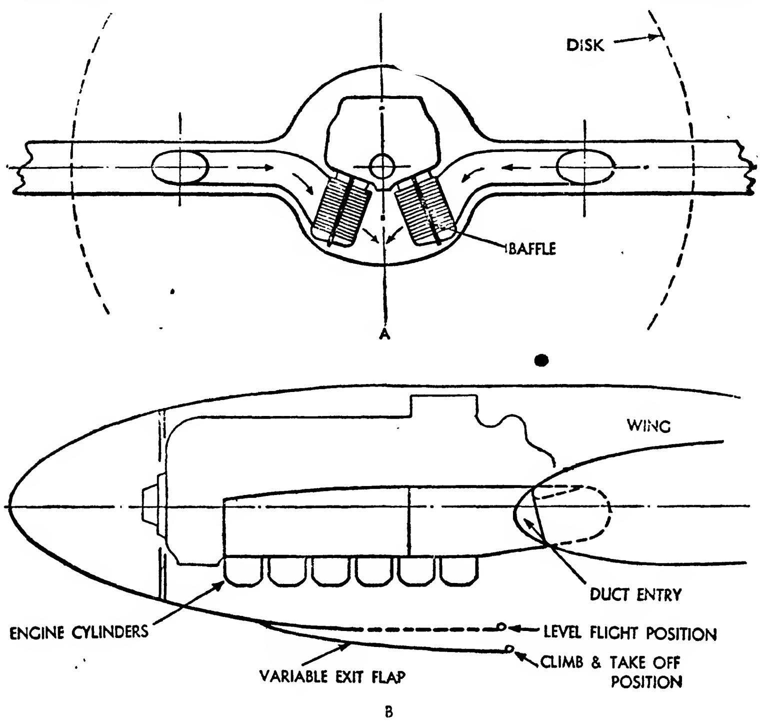
COOLING. A system whereby the surplus heat generated in the cylinders of an internal-combustion engine is radiated to the atmosphere. It can be done either directly or indirectly; directly, by allowing cold air to pass round the cylinders, which, in this case, are cast with radial fins to present as large a surface as possible to the cooling draught; or indirectly, by a system of cylinder jackets through which water or some other liquid circulates to an air-cooled radiator. In general, air-cooling is used for motor cycles and radial aero engines while most cars and heavier vehicles and inline type aero engines are water-cooled.

Two main methods of water-cooling are employed: the thermo-syphon and forced circulation systems. In thermo-syphon cooling, shown in Fig. 1, circulation is dependent upon the natural fact that hot water rises and cold water sinks; in the forced-



THERMO-SYPHON COOLING

Fig. 1. Diagram showing direction of water flow in cooling system of a Ford motor-car engine. As the water in the cylinder block heats up, it rises to the tank above the radiator; on cooling, it descends through the radiator and flows again into the cylinder block through the inlet hose as indicated by arrows.



AERO-ENGINE DUCTED COOLING SYSTEM

Fig. 2. Front view, A, and side view, B, of ducted cooling system in a DH 91 "Albatross". Note variable air-exit flap to meet increased cooling requirements.

circulation method a pump is fitted to maintain circulation. In both systems the water heated by the cylinders rises and flows through an outlet pipe to the top tank of the radiator to be cooled, while cooled water enters the cylinder jackets from the bottom tank. Large-diameter pipes connect the water-jackets to the radiator where natural circulation is used, but smaller pipes can be tolerated in forced-circulation systems because the pump accelerates the flow and the water is circulated more rapidly. A fan rotated by the engine draws air round the radiator tubes and assists in cooling the water. See RADIATOR.

Liquid cooling on aircraft may be achieved in a variety of ways. The liquid originally in common use was water at atmospheric pressure. This suffered from the disadvantage that, owing to decreased air pressure, the boiling point of water falls as altitude is increased. It was therefore necessary to use a very large radiator and run the engine at a low temperature to prevent the water from boiling away.

One attempt to overcome this difficulty was the development of *evaporative* or *steam* cooling. In this system the water was allowed to boil in the cylinder jacket and was then passed to a condenser placed in the airstream. A variant of this scheme was *composite* cooling, in which the water was allowed to boil only under high-power conditions, while at cruising-power outputs the system functioned as an ordinary liquid cooling system.

The above schemes were, however,

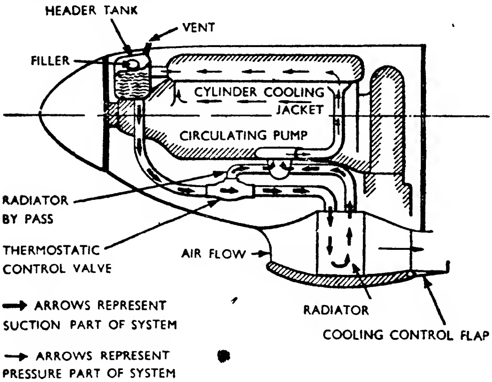


Fig. 3. Essential features of a cooling system for a liquid-cooled aircraft engine.

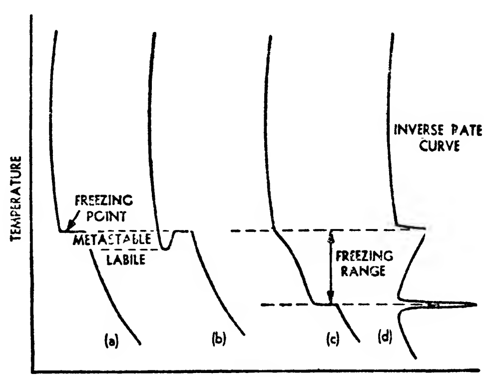
abandoned in favour of the use of ethylene glycol as the cooling liquid. This liquid has a higher boiling-point than water and is thus favourable to the use of smaller radiators and, hence, causes lower drag.

Difficulties arose, however, due to corrosion of the cooling systems, and the fluid now in common use is a mixture of ethylene glycol and water. The quantity of ethylene glycol present in the fluid is sufficient to prevent freezing while the aircraft is on the ground and also appreciably to raise the boiling-point of the mixture, while avoiding the corrosion troubles mentioned above. In order to keep the engine at a reasonable temperature an excessively low temperature being undesirable, as well as is an excessively high one, the whole of the cooling system is kept under pressure. The boiling-point of the fluid is thus increased, which enables a smaller radiator to be used.

Ducted cooling involves the enclosure of the radiator, or cylinders of an air-cooled engine, in a duct, instead of allowing them to project into the main airstream flowing past the machine. Fig. 2 shows an air-cooled ducted cooling system as exemplified by the Gipsy Twelve installations in the De Havilland Albatross. A typical water-cooled engine installation with a ducted radiator is shown in Fig. 3.

The flow of air past the cooling surfaces is usually controlled by a flap at the exit from the radiator, or by a gill ring round the air exit from a radial engine cowling. There are certain gains in cooling, notably at low forward speeds, to be obtained by the use of a fan in the cooling-air entry. The German F.W. 190 fighter is probably the best-known example of the use of a fan to assist cooling.

COOLING CURVE. A graph obtained by plotting against time the temperature of a piece of metal cooling under conditions which remain constant. The usual form of curve given by a pure metal as it changes from the liquid to the solid state is shown at (a) in the diagram which appears below. The horizontal portion of the curve is due to the release of heat energy during the process of solidification. When completely solid, the metal again cools normally. If cooling



Typical cooling curves for pure metals and alloys.

is unduly rapid, solidification may not occur at the normal melting point, but at some lower temperature.

Finally, crystallization occurs spontaneously throughout the mass of the metal, and the temperature rises to the true melting-point as depicted at (b). The range of temperature below the melting point in which a metal may remain liquid is termed the metastable range. Below this range the metal is said to be in the labile state. Similar forms of curve can be obtained with alloys in the solid state, provided they undergo a definite change in micro-structure at a fixed temperature.

Cooling curves representing the solidification of alloys differ from those shown for pure metal. In most cases alloys do not freeze at a definite temperature but pass through a pasty range. The form of curve generally obtained is shown at section (c). This type of curve often fails to indicate with any certainty the exact temperature at which crystallization commences. Much better results can, however, be obtained by plotting temperature against the time required to cool through a small interval of temperature. Such a curve is shown in section (d). Cooling curves are of great value in the determination of equilibrium diagrams (q.v.). See also METASTABLE STATE.

COMPOSITE COOLING, see COOLING.

COPE. The top half of a mould. See MOULDING BOXES.

COPING. The capping material covering the top of a wall. Its function is to shed the water from the wall and thereby prevent damp from penetrating the top of the wall and from running down the surfaces. Copings may comprise stonework, brickwork or terra-cotta. See PARAPET WALL.

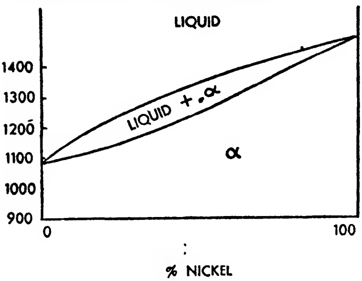
COPPER (Cu). Atomic no. 29; atomic wt. 63·57; a reddish-brown metal of comparative scarcity among the earth's elements; density 8·86; m.p. 1,083 deg. C.; b.p. 2,310 deg. C. Native copper occurs in Russia, Sweden, and near Lake Superior. The commonest copper ore is copper pyrites, a sulphide of copper and iron of variable composition. Copper readily tarnishes in damp air. Pure copper is obtained by passing an electric current through a copper sulphate bath with copper anodes; it has a high thermal and electrical conductivity. Copper is monovalent or divalent and chemically resembles silver. It forms two classes of compounds, the cuprous salts, in which it is monovalent, and the cupric salts, in which it is divalent.

The commonest copper compound is cupric sulphate, $CuSO_4.5H_2O$, which forms large, deep-blue crystals and is known as blue vitriol.

The alloys of copper are very numerous, some varieties of brass containing 70 per cent of copper and 30 per cent of zinc. Aluminium brass contains 70 per cent copper, 28 per cent zinc, and 2 per cent aluminium. Dutch metal contains 80 per cent copper and 20 per cent zinc. Muntz metal contains 60 per cent copper and 40 per cent zinc. Phosphor bronze has about 90 per cent copper, 10 per cent tin, and 0·3 per cent phosphorus. Nickel silver has up to 30 per cent nickel, the remainder being copper and zinc, often about twice as much copper as zinc. Monel metal contains about 68 per cent nickel, 30 per cent copper, 1½ per cent iron, and a little manganese, silicon and carbon. Gunmetal contains about 88 per cent copper, 10 per cent tin, and 2 per cent zinc. The compositions mentioned above are only approximate, and there are many special varieties intended for special purposes.

COPPER LOSS. The electrical power wasted as heat in a circuit not designed for the production of heat or light. This loss is due to the presence of resistance and is given by multiplying the square of the current by the resistance. Thus a current of 2 amps flowing in a resistance of 3 ohms causes a copper loss of $(2^2 \times 3) = 12$ watts. Synonyms: I^2R Loss, Resistance Loss. See WATT.

COPPER-NICKEL ALLOYS. Copper and nickel may be alloyed together in any proportions to form a



Equilibrium diagram showing proportions in which copper and nickel may be alloyed together to form a solid phase. These have various uses as described in the accompanying text.

single solid phase as shown by the equilibrium diagram given here. Almost the whole range of these alloys is of practical value, the best-known being those containing 4 to 10, 20 to 30, 40 to 45, and 60 to 70 per cent of nickel.

The 4 to 10 per cent nickel alloys are employed for high-duty motor slip rings; the 20 to 30 per cent nickel alloys mainly for the manufacture of condenser tubes, valve castings etc., the 40 to 45 per cent alloys for electrical resistance work, and the 60 to 70 per cent alloys for many engineering applications where high resistance to corrosion combined with strength is desired. This last group includes the well-known Monel metal (q.v.).

Copper-nickel alloys are liable in melting to pick-up sulphur with deleterious results. On solidification, the sulphur is deposited in the form of brittle films of nickel sulphide at the grain boundaries, causing a serious fall in tensile strength and ductility. Carbon is also harmful. The absorption of both these elements during melting may be prevented by maintaining an oxidizing atmosphere over the melt.

COPPER-OXIDE RECTIFIER, see METAL RECTIFIER.

COPPER PYRITES, see COPPER.

CORBEL. A projection from the wall face, intended to support a superimposed weight. The term is often applied to courses of bricks projecting from the wall face to receive a timber wall-plate for supporting the ends of timber floor joists; also to a stone projecting from the wall face to support the foot of a roof truss, or other superimposed load.

CORE. The term applied to those parts of a mould which are made separately in a special former or core-box, and afterwards assembled in the mould. Cores are most often employed to form internal holes or cavities in the casting, but are also used for parts of the mould that would be difficult or expensive to make by means of a pattern. In some cases a complete mould may be constructed entirely from cores by assembling a number together.

In machine moulding, cores may be employed to fit under lugs and projections to prevent the formation of loose patches in the sand. Large cores require adequate reinforcement by core-irons, but small cores may be left unsupported if a good core sand is employed. Although core-boxes are used to form the majority of cores, large irregular cores and their core-irons are generally made in the mould itself, the cost of core-boxes being heavy. This is done by building the mould, or part mould, and lining it with clay equal in thickness to that of the metal required. The mould so prepared is used as a core-box.

CORE BARREL. A piece of iron, steel or cast-iron piping used to form the centre of a cylindrical loam core. The barrel should be drilled with many small holes to permit adequate venting. During the manufacture of a loam core, the barrel is supported and rotated in "V" bearings. To permit easy rotation, the ends of large barrels may be reduced in section. See BARREL CORES.

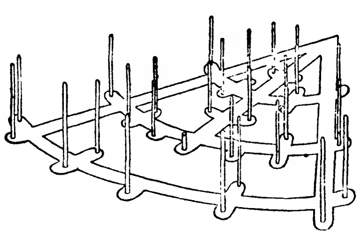
CORE BINDERS. Materials used in foundry work to improve the strength of cores (q.v.). Substances such as linseed and other setting oils, molasses, and latex are commonly employed. These, mixed with a silica sand, form very strong cores which,

when dried, need little or no reinforcement. Moreover, since sands prepared in this way are very permeable, a ready escape is provided for the gases generated when the metal is poured into the mould. Many proprietary compounds are available, and one should be selected according to whether a high-green bond or great strength after drying is required. See OIL SAND.

CORED STRUCTURE. A structure often resulting when a binary alloy solidifies. In addition to the grain boundaries, the dendritic core of each crystal is also visible under the microscope. This is due to a difference in composition between the metal first deposited and that obtained later.

For example, copper-tin alloys containing 10 per cent tin first deposit an alloy containing only 2 per cent tin, this difference in composition giving different etching characteristics to the various parts of the crystal grain. Cored structures can generally be obliterated by prolonged annealing, the composition becoming uniform throughout each grain by diffusion. See CRYSTAL GRAIN and DENDRITE.

CORE IRONS. Pieces of metal used in foundry work to reinforce a core. A straight steel bar may be used for a



Typical core iron of the type used for large irregular cores and made in the mould, rather than in the bed.

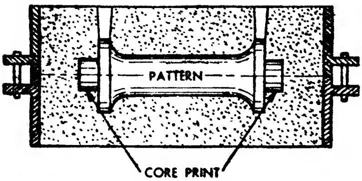
simple core, but for more complicated shapes pieces of wrought-iron rod, suitably bent, are often employed. Large cores need more reinforcement than can be given by these simple means. For this purpose, special castings are made in a part of the foundry set aside for this work (see BED). In making these castings, the shape of the core is marked-out on the bed, the core box acting as a guide, and a grid pattern somewhat smaller than the required core is shaped in the sand by means of a dabber. Prongs of the required length are formed by inserting a prodder bar of suitable size into the sand at various points. In this way cast-iron prongs are formed when the core iron is cast. In some cases it is desirable to be able to bend the prongs, and for this reason pieces of wrought-iron may be inserted instead of using a prodder bar. The ends of the wrought-iron rods fuse when the metal is poured and so become fixed to the grid. Core irons for large irregular cores cannot be made in the bed since they have no flat surface. Such core irons, shown in the accompanying illustration, are generally made in the mould.

CORE-MAKING. In foundry work cores may be made from green sand, dry sand, loam and special core-sands, whichever is the most appropriate. Core-making is regarded as less skilled than moulding, and most moulders receive their first training on the core bench. For most cores a special former or core-box is required.

Small cores are most commonly made in oil-sand (q.v.), which is merely pressed into the box with the fingers, the box rapped and the core withdrawn, being then transferred to a plate or cradle and baked hard.

The making of larger cores, needing considerable reinforcement, requires more skill, and the same methods may be used as are applied in moulding. Careful attention, however, must be paid to venting. Large cores built in the mould itself are generally made by the moulder, not the core-maker; such cores require considerable skill and experience.

CORE PRINT. A projection on a pattern, used to form a register in the mould, by which the core is supported and retained in the correct position. The core-box must provide for similar projections on the core to



Pipe mould showing use of core prints.

those on the pattern. A simple pipe pattern, in which the core prints are indicated, and a cross section of the finished mould, are shown in the illustration.

CORE SAND. Sand prepared specially for core making. See CORE BINDERS.

CORE-TYPE TRANSFORMER, see SHELL-TYPE TRANSFORMER.

CORNICE. The moulded projecting course which crowns that part of the building to which it is affixed. One important function of a cornice is to protect a wall from moisture; therefore provision should be made for the proper discharge of rain water from the projecting top surface. A continuous "drip" should be provided as near to the nosing of the cornice as the detail will allow.

COROMANDEL, see MAHOGANY.

CORONA. An electrical discharge from a conductor, due to a high-potential gradient at its surface. It may be accompanied by a hissing sound and a violet light which is brighter where sharp points exist on the conductor. See POTENTIAL GRADIENT.

CORROSION. The destruction of solids, particularly metals and alloys, by chemical attack produced by the media with which they are in contact, as for example the rusting of iron. In ordinary atmospheres containing moisture and carbon dioxide, rusting of iron readily occurs. A dark-green film of basic ferrous carbonate is first produced. This is oxidized by the air to form red ferric hydroxide, or rust, at the same time setting free carbon dioxide to attack the underlying metal so producing more basic ferrous carbonate. The coating of rust is porous, permitting the access of moisture so that the action continues indefinitely. Dry air containing carbon dioxide, or moist air entirely free from this gas, does not produce rusting.

Industrial atmospheres containing sulphurous and sulphuric acids etc., and marine atmospheres containing salt, greatly accelerate the rate of corrosion. In some cases, the corrosion product formed stifles any further action. For example, copper sheet used for roofing church spires etc., soon acquires a green patina which protects the underlying copper against further attack.

Electrolytic or galvanic corrosion can be produced when two dissimilar metals or alloys, in contact with each other, are immersed wholly or partially in an electrolyte. Under these conditions, the less noble metal or alloy is attacked more violently than it would be if immersed alone in the same electrolyte, whereas the more noble metal, or that which does not easily combine with non-metals, is protected from attack. It is sometimes possible to take advantage of this phenomena in order to prevent corrosion. For example, it is common practice to fit steel plates inside marine condensers. These are rapidly attacked by the sea water, but the more costly brass parts of the condenser are protected.

CORROSIVE SUBLIMATE, see MERCURY.

CORRUGATION. The wavy shape imparted to sheet metal for certain roof structures. Two types of machine are used for this purpose: (a) the single-blow, or press design, and (b) the rotary corrugator. In the former and simpler type, the corrugations are set by a second blow, which helps to produce a regular contour, and this is the method most widely used in Britain. Where appearance is of secondary importance, the rotary design can give increased output, the sheets being passed straight through.

COSLETTIZING. The immersion of ferrous metal parts in a boiling solution of phosphoric acid saturated with ferrous phosphate, to produce an

insoluble rust-resisting grey-phosphate coating on the metal surface. The solution is prepared by dissolving iron filings in phosphoric acid.

The coslettizing process is a relatively slow one, taking about two hours to produce a good phosphate coating. Moreover, the solution is unstable, as the ferrous phosphate tends to oxidize rapidly with the precipitation of the insoluble ferric phosphate. It has therefore been largely superseded by parkerizing (q.v.). Phosphate films are generally impregnated with oils or lacquers to improve their rust-resisting qualities.

COTTER. A special type of key employed to join machine or engine parts in which either tensile or compressive forces, or both, may operate. Its best-known applications are in the moving parts (connecting rods and valve gear) of steam engines, compressors etc. A customary cross-section for a cotter is a rectangular form, often with radiused corners, the length generally being sufficient to allow the cotter to be driven farther in if any slackness arises in service.

Cotters are frequently tapered; the steepness of the taper will decide the tightness with which the cotter can wedge against the component parts through which it is driven. A much used taper in locomotive connecting-rod cotters is $\frac{3}{16}$ in. per foot; i.e. 1 in 64. The slots through which the cotter is fixed are so cut that the two

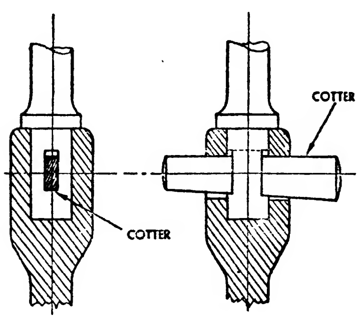


Fig. 1. Common form of cotter of the type widely used to hold together moving parts of an engine or machine.

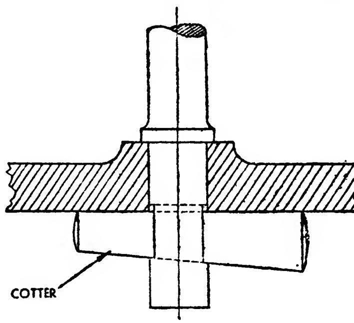


Fig. 2. Machine parts are often secured by a cotter tapered as shown.

parts which it connects are drawn firmly together, bearing on alternate sides of the cotter as shown in Fig. 1. Another form of cotter, Fig. 2, is often used for holding down machine parts.

COTTONWOOD, see CANARY WOOD.

COULOMB. A unit quantity of electricity, which passes in a circuit when one ampere flows for one second. Synonym: Ampere-second. See AMPERE-HOUR.

COULOMB'S LAW. The law relating to the forces between electrical charges. It states that the force is proportional to the product of the charges divided by the square of the distance between them. See CHARGE.

COULOMETER, see VOLTAMETER.

COUMARONE AND INDENE RESINS. Resins prepared from coal-tar naphtha by treating it with strong sulphuric acid. The resins have melting points from about 50 to 150 deg. C. and are largely used in the manufacture of varnishes.

COUNTER BATTENS, see JOINTS.

COUNTERPOISE. An arrangement used in place of the more conventional earth connexion for a radio transmitter or receiver. When the earth itself is dry or a poor electrical conductor, it may be desirable to use an artificial "earth" consisting of a network, or mesh, of wires placed above the ground and insulated from it. Such a system in effect replaces the earth, provided the wires of the mesh

are sufficiently close to one another to form a conductive layer. The associated aerial is, of course, erected above the counterpoise.

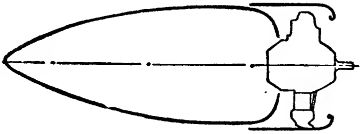
COUNTERSINKING. The operation of forming a conical seating to receive the head of a screw so that no part of it will project above a given surface. The work is usually carried out on a drilling machine, using a tool having cutting edges to suit the angle of conical shape specified. A "pilot" countersink is used when the hole for the body of the screw has already been drilled. As a time-saver, however, the drill for the screw-body and the countersink for the conical head may be combined in one tool.

COVE. A concave moulding usually situated at the junctions of walls and ceilings, the purpose being to provide a hollow curve in place of a sharp angle of intersection.

COVER COAT (Painting). The finish coating of enamel on coachwork, sometimes called *top* coat or *finish* coat. The cover coat may consist of two coats of the same enamel or two coats of different enamel. Whatever the case may be, the enamel shop generally refers to the first coating as the "half-cover coat" or "first coat" over which the finished coating is applied, usually at the same weight of application as the first coat; hence the term "half-cover coat."

In modern practice, a great deal of enamelling consists of one cover-coat enamel applied over the ground-coat enamel.

COWLING. The panels which enclose an aircraft engine. The cowling of a radial engine also serves to guide the flow of cooling air. The form at present most common was developed by the National Advisory Committee for Aeronautics (N.A.C.A.) research



Cross-sectional view of a typical cowling for a radial aircraft engine.

workers in the U.S.A. and is usually referred to as "N.A.C.A. long-chord cowling". The illustration shows cowling for a radial installation.

CRACK DETECTION. Cracks are often produced in metal articles during their manufacture or in service. These cracks are often so fine as to be invisible to the naked eye, but nevertheless they may lead to premature failure of stressed components. Methods of detecting such cracks have therefore been devised.

In the magnetic method, applicable only to materials which may be magnetized, the article is placed across the poles of an electromagnet. An oil containing fine iron particles is poured over the article. The iron particles collect at the cracks, making them readily visible as dark lines.

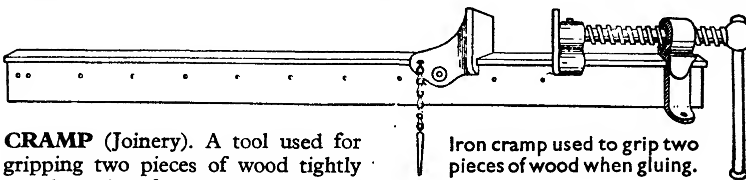
A simple method which requires no special apparatus involves immersion of the article in oil, wiping dry and then coating with whiting. The oil seeps out of the cracks staining the whiting.

A similar but rather more sensitive method has been developed recently. The article is first immersed in a warm liquid containing a fluorescent material. This liquid is washed off, leaving fluorescent material in the cracks. Examination in a darkened room, under the light of an ultra-violet lamp, shows the cracks as bright lines against a dark background.

CRACKING. A technical term used in the petroleum industry, meaning the breakdown of a petroleum fraction by heat treatment into compounds of smaller molecular weight.

CRACKING OF PAINT. Fracture of the paint film which takes place with ageing. All films tend to shrink with ageing and if the power developed by the surface constriction is greater than the grip of the film upon the groundwork, the film body will crack.

Cracking is usually caused by painting with a hard-drying material upon a surface of a more elastic character. Excess of drier in the final coat of paint, and the use of hard or indoor varnish upon external surfaces, are other common causes of cracking.



Iron cramp used to grip two pieces of wood when gluing.

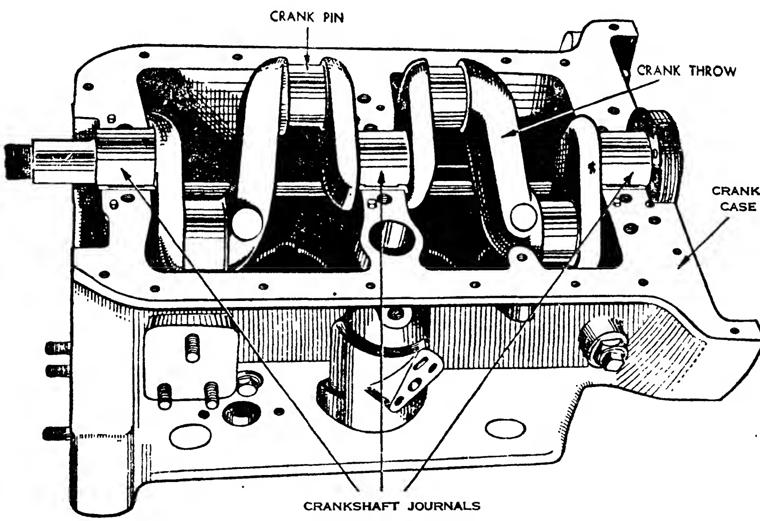
CRAMP (Joinery). A tool used for gripping two pieces of wood tightly together when forming a glued joint, or for drawing the parts of a frame together. The illustration shows the type of iron cramp in general use. The holes and pins allow the cramping shoulders to be set within, say, an inch of the required dimension, after which they can be tightened against the work by means of the screwed head.

CRANK, see LEVER.

CRANKCASE. That part of an engine enclosing the crankshaft (q.v.); usually a casting of aluminium alloy or iron made up in two parts. In the heavier types of commercial motor vehicle the crankcase is divided on the centre line of the crankshaft, the housings for crankshaft bearings being integral with the upper half, which also supports the cylinder assembly; the lower half serves as a reservoir for the engine lubricant and is secured to the upper portion by bolts or set-screws. On most light vehicles, the upper half of the crankcase and cylinder are cast in one block, and this casting is sometimes extended so that only a flat cover on the engine base is required. See MONOBLOC.

CRANK PIN, see CRANKSHAFT.

CRANKSHAFT. The shaft carrying the cranks by means of which the up-and-down movement of the pistons of any reciprocating engine is converted into rotary motion. Crankshafts vary widely in size, the large types having separate cranks keyed on to them, while the smaller sizes, particularly in internal-combustion engines are usually a one-piece steel forging



INTERNAL-COMBUSTION ENGINE CRANKSHAFT

Crankshaft for four-cylinder engine shown in position in the inverted engine. Main-bearing caps and connecting-rod big ends have been removed to show journals.

and are formed with a number of U-shaped bends, the number of such bends, or "throws," corresponding, except in "V" engines, with the number of engine cylinders. A typical crankshaft for a four-cylinder engine is shown in the illustration.

The shaft on each side of a throw is in perfect alignment; as the shaft rotates, the throw describes a circle the diameter of which determines the stroke of the piston in the cylinder, the big-end bearing of the connecting rod (q.v.) being secured to the throw on what is termed the crank pin. The shaft revolves on main bearings supported in the crankcase, and there may be two, three or more according to design. That part of the shaft between the main journal and the crank pin is termed the crank web, these webs being weighted to give balance.

CRANK WEB, see CRANKSHAFT.

CREOSOTE. A thin, tar-like liquid obtained mainly from the distillation of coal tar. A strong antiseptic, it is used for protecting rough timber structures from mechanical disintegration by weathering, and from the destructive action of moulds, fungoid growths and insects. The best protection is obtained by immersing the parts in the liquid under pressure in containers; when this is not possible, the priming coat is brushed on hot. After erection of the structure, creosote may be applied cold.

CRESOLS, see COAL.

CRIMPING. A series of puckers imposed on the edge of a sheet of metal to reduce the circumference or outline as, for example, preparatory to the union of two pipes of similar size.

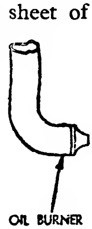
CRITICAL TEMPERATURE. The temperature at which a phase change takes place in a metal or alloy. In equilibrium diagrams, such temperatures are indicated by horizontal or inclined lines placed below the solidus. Alloys may pass through none, one, or several critical temperatures on heating-up to the solidus temperature.

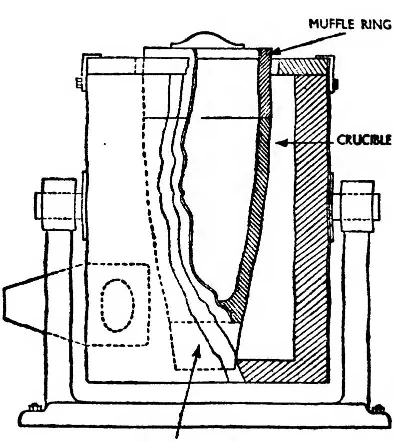
CROSS-CUT FILE, see FILE.

CROSS MODULATION. Modulation of one radio signal by another; the two cannot afterwards be separated by tuning. It usually arises from overloading an early valve stage by one or both of the signals concerned.

CROSS-TALK. Unintentional interference between adjacent telephone circuits, which results in the overhearing of conversation on other lines.

CRUCIBLE FURNACE. A furnace in which the metal is melted in a crucible or pot which is heated externally as shown in the accompanying diagram. Such furnaces may be fired by coke, gas or oil, whichever is most suitable. As the products of combustion do not as a rule enter the crucible, contamination of the metal by the furnace gas is to a large extent prevented. Melting in crucible furnaces is most commonly employed for the non-ferrous metals. It is also convenient for special alloy cast-iron as the composition of the melt can be accurately controlled. For the non-ferrous foundry, 200 to 1,000 lb. furnaces are most useful, but for





Diagrammatic view of oil-fired tilting crucible furnace. The tilting mechanism has been purposely omitted.

special requirements sizes from a few pounds up to a maximum of one ton are available.

CRUCIBLE STEEL. Steel made by a process initiated by Robert Huntsman about 1740. It is made from wrought-iron of high quality, low in phosphorus content, which is cut into small pieces, placed in an airtight crucible with the requisite quantity of powdered charcoal, and melted in a furnace. By making the steel in this manner, a very close control can be established over its qualities, but the process is expensive because the amounts produced are small.

Although the best results can be obtained only by the use of wrought-iron, an inferior quality can be manufactured by substituting open-hearth mild steel or Bessemer steel. The crucibles used in the making of this quality of steel are of good quality clay, with an admixture of powdered coke amounting to about 5 per cent by weight. The capacity of the crucibles employed varies from about 70 to 200 lb.

Graphite crucibles are now being used as these do not require so much care in handling and will withstand a greater number of heatings. The carbon content of steels made by this process ranges from 0·7 to 1·5 per cent. Crucible steel is suitable for making many kinds of tools such as chisels, taps, dies, reamers etc. It is hardened by heating-up to from 760 to 800 deg. C. followed by quenching in cold water, after which it must be tempered.

CRYOLITE, see ALUMINIUM.

CRYSTAL DETECTOR. An early form of simple demodulator making use of the property of unilateral conductivity of certain crystals (q.v.) or combinations of crystals.

CRYSTAL GRAIN. A unit in a mass of metal. In each crystal grain the atoms are geometrically arranged with definite axes of symmetry. The direction of these axes is uniform within each crystal grain but may vary from one grain to another. Under the microscope, these grains appear as irregularly shaped areas, but this is simply due to the constrained conditions under which they are formed, each crystal growing until it is prevented by contact with a neighbouring crystal.

Under suitable conditions, geometrical shapes may be formed, as, for example, when lead containing a few per cent of antimony solidifies. Antimony separates first in the form of cuboids which float in the lead and are therefore free to develop their true crystalline form.

CRYSTAL MICROPHONE, see MICROPHONE.

CRYSTALS (Chemistry). Most solid bodies are crystalline, though the individual crystals may be very small and imperfect. It is easy to obtain large and practically perfect crystals of some solids, e.g., alum, copper sulphate and lead nitrate. Among minerals, the crystals of fluorspar, galena (lead sulphide) and some of the felspars are large and easily recognized. A study of crystals has revealed that they form seven systems, or types of structure, depending on the axes of the crystal.

A crystal of common salt, NaCl, is not a collection of separate molecules of NaCl, but a mass of alternate atoms, or ions, of Na and Cl arranged in three dimensions, so that, except at the surface of the crystal, each sodium atom is surrounded by six chlorine atoms and each chlorine atom is surrounded by six sodium atoms. These atoms are held together by electrical attractions, or electrons, between them and all their neighbours.

An atom has no very definite shape, but as the electrons can move round the nucleus the atom may roughly be regarded as a sphere, and the problem of arranging them in some close-packing system depends on the relative sizes of the spheres; in common salt those of the sodium are all of one size; those of the chlorine are all of another size. The result is that the way the atoms are packed in a crystal partly depends on the valency (q.v.), or external electrons, of the elements concerned, and

partly on the sizes of the atoms. Common salt is a very simple case, but where three, four, or more elements are concerned the problem is more complicated. In alum, in which potassium, aluminium, sulphur, hydrogen and oxygen spheres are all fitted in, the actual arrangement is not what would be expected from an arrangement of separate molecules of potassium sulphate, aluminium sulphate and water.

Substances that crystallize in the same system in the same form and with similar angles, are called isomorphous, and this similarity is called isomorphism. Thus the crystals of potassium sulphate, rubidium sulphate and caesium sulphate are practically isomorphous. Ferrous sulphate, $FeSO_4.7H_2O$, and cobalt sulphate, $CoSO_4.7H_2O$, are practically isomorphous, their crystals belonging to the monoclinic system.

Similarly, the salts copper sulphate, $CuSO_4.5H_2O$, and manganese sulphate, $MnSO_4.5H_2O$, are practically isomorphous, crystallizing in the triclinic system. It is not necessary that the chemical composition of two isomorphous substances should be exactly similar; thus aragonite, a variety of calcium carbonate, is isomorphous with sodium nitrate, although calcium is not closely related chemically to sodium nor carbon to nitrogen. It is possible to prepare mixed crystals of isomorphous substances, and this fact shows, as do some others, that although chemical compounds in the main differ entirely from mechanical mixtures, there are intermediate states. There are substances, such as red lead, that have no really definite chemical composition, and yet seem not to be merely mechanical mixtures.

CRYSTALS (Radio). Certain crystals and combinations of crystals possess the property of conducting fairly freely in one direction while presenting a high resistance in the reverse direction.

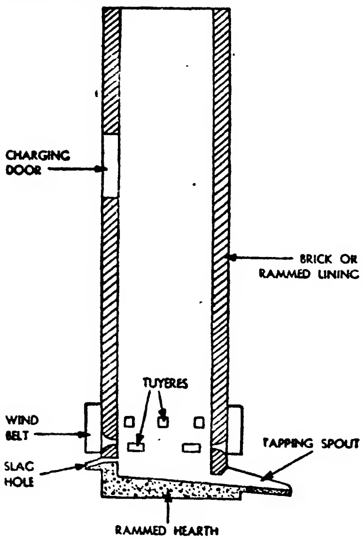
These crystals were used in early radio receivers to rectify the radio-frequency signal, that is, to secure uni-directional pulses able to operate the head-phones.

Other crystals, such as quartz (q.v.), when cut into slices, vibrate mechanically when a suitable alternating voltage is applied to the opposite faces. They also possess the reciprocal property of producing, when stressed mechanically, a potential difference between the faces so stressed. Their natural frequency is determined primarily by the dimensions of the crystal and the angle relative to an axis of the main crystal from which the slice is cut. Under suitable conditions, they can be very stable in operation and in many respects behave like a high-Q conventional tuned circuit. This effect is said to be *piezo-electric* (pressure-electric).

By incorporating specially cut crystals in transmitters and, occasionally, receivers, stable operations on any given frequency may be secured. *Rochelle salt* crystals, in particular, possess marked piezo-electric properties and are often used in gramophone pick-ups, microphones and loud-speakers. See CRYSTAL DETECTOR.

CUBIC CAPACITY. The holding capacity of any vessel or container. In internal-combustion engines, for instance, the cubic capacity is the volume of the combustion chamber plus the volume of that part of the cylinder traversed by the piston in its stroke. For rating purposes, however, the cubic capacity is confined to the piston-swept volume and does not include that of the combustion chamber. The total capacity of the engine equals the piston-swept volume of one cylinder multiplied by the number of cylinders, e.g. 1½ litre, 4½ litre etc.

CUPOLA. A tall cylindrical-shaft furnace used for melting cast-iron. A section of such a furnace is shown in the illustration opposite. The outer shell is of mild-steel plate, and is lined with firebricks or rammed ganister. Air is supplied by means of a blower to the wind belt, and thence passes into the shaft through a number of holes, or tuyères. The hearth of the furnace should slope towards the tap



Whereas cupola furnaces are used almost exclusively for melting cast-iron, smaller versions are widely employed for melting copper where considerable quantities are required.

hole and spout. About 15 to 18 in. above the hearth a second hole is provided for the removal of slag. This type of furnace is always fired by coke, which is introduced, as are the charges of metal, by means of a door placed near the top of the furnace.

In starting the cupola, a wood fire is lighted on the hearth, and this is gradually built up with coke until it is well above the tuyères. The breast-plate at the bottom of the furnace is now closed and the blast turned gently on. Alternate charges of metal and coke are then added up to the level of the charging door. For each ton of metal about 50 lbs. of limestone should be added. The tap hole is then closed, the blast turned full on, and melting proceeds rapidly. The rate of melting depends upon the diameter of the furnace, and is generally about 10 lb. per hour for every square inch of cross section. Metal may be run out as required, and should never be allowed to accumulate in the well until it reaches the slag hole.

The limestone added forms a fluid slag with the ash from the coke and impurities and sand adhering to the metal charged. This slag is run off through the slag hole, which may be left open during the run of the cupola. After each day's run the furnace must be cleaned of all slag and the lining repaired with ganister. At least two cupolas are therefore necessary, so that one may be run while the other is repaired.

CUPRIC SALTS, see COPPER.

CUPPING TEST. A means of assessing the ability of sheet metal to withstand and transmit strain in a press operation. Cupping tests may be divided into two classes: (a) those which use fluid, such as the Jovignot method, and (b) those which use a solid punch. While this test does not fully satisfy the need for a complete test of drawability (q.v.), it does provide useful data thereon, being multi-directional.

In the Jovignot method, the sheet to be tested is clamped, by means of a screw press, firmly between two annular jaws. An oil-filled reservoir below the test-piece communicates with a screw pump. As pressure is applied by means of this pump, the test-piece assumes the form of a dome. The pressure is indicated by a gauge mounted on the pump, and the height of the dome is given by a dial indicator, the feeler of which follows all the movements of the top of the cup pressed in the metal. The test is continued until fracture occurs, this stage being indicated by a rapid drop in the pressure, and frequently, by an escape of oil at the point of fracture.

In the Erichsen test, which is typical and widely used, a hemispherical punch (20 mm. diameter) is forced into a specimen of sheet metal, 3½ in. square, held between a radiused die (27 mm. diameter) and a pressure plate. The metal is thus distended into the shape of a cup, pressure being applied until fracture occurs. The depth of the cup is measured on a

micrometer scale, and gives an indication of the ductility.

A rough "orange-peel" appearance on the dome surface indicates metal with large grain-size. Such material is ductile, but may not be sufficiently tenacious to withstand severe deformation; polishing costs would in any case be high. In sheet without directional properties, the fracture will run circumferentially round the dome.

Depth of cup, appearance of dome surface, and direction of fracture give useful information concerning deep-drawing quality. It is now generally concluded that no one cupping test is superior to the others, the main advantages in their use being that they are simple and inexpensive to make and afford a guide as to the probable behaviour of metal in a press.

CUPROUS SALTS, see COPPER.

CURDLING OF PAINT. Transformations which take place in the liquid character of paint, either in the can or during brushing, also known as *gelation*, *feeding up* or *livering;* the paint assumes a stiff, jelly-like consistency or curls up into small, pellet-like lumps under the brush. This is due to use of the wrong type of drier with the other ingredients of the paint. Such paint is useless and should be destroyed.

CURRENT Symbol: I. A flow of electricity, conventionally from the positive terminal of a source back to its negative terminal. It should be noted that the electron flow is in the opposite direction. The practical unit of current is the ampere (q.v.).

CURRENT DENSITY. The electric current in a conductor divided by the cross-section of the conductor. It is conveniently expressed in amperes per square cm. or square in.

CURRENT FEED-BACK, see NEGATIVE FEED-BACK.

CURRENT-LIMITING REACTOR. A reactor introduced into an electrical circuit to limit the current to some specified value. The effect produced in an A.C. circuit is similar to that of a resistor but the power wasted is much less. See REACTOR.

CURRENT-TRANSFORMER. An electrical transformer having its primary series-connected, while its secondary is usually connected to a measuring instrument or to a relay. The secondary current should be a fixed proportion of the primary current and usually has a full-load value of 5 amps., whatever the turns ratio. See TRANSFORMER.

CUT-OUT. An electro-mechanical device for automatically opening a circuit; used, generally, in battery charging, as in a motor vehicle. automatically completes the charging circuit when the generator voltage exceeds that of the battery and opens the circuit when the current reverses, or is about to reverse, as a result of reduced generator voltage.

CUT STRING (Building), see STAIRS.

CUTTERCRUSH. A blocking method of printing used largely for the production of showcards. The letters or characters are made of brass or steel in the form of a hollowed block with cutting edges. The block combination is heated in the press, the base card placed in position and covered by gummed-paper sheets or strips of contrasting colour or colours. Pressure is then applied to the block, and the edges force the gummed paper into the card base and cause firm adhesion. The surplus paper is stripped away, leaving the characters clean and of distinctive form against the contrasting colour of the base.

CUTTING ANGLE. The angle to which a tool is ground or set for a particular cutting purpose, chiefly with reference to lathe work, but also of importance in hand chisels, drills etc. With lathe tools the angles to consider are the front and side clearance angles, and the top and side rake.

The front and side clearance angles are the same for all tools and all materials, namely 3 deg. In general, the top and side rake are approximately equal, except for hard materials and high rates of traverse; in the latter case the side rake is greater than the top rake. There is no such thing as an

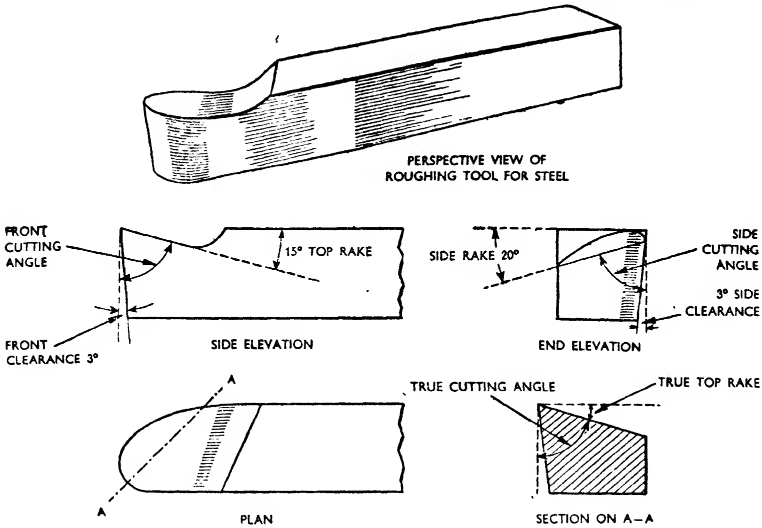


Fig. 1. Front and side angles and top and side rake are of the utmost importance in grinding and setting lathe tools. The example above is used for cutting steel.

"average" lathe tool, but Fig. 1 shows a specimen of one which is in general use.

The table given indicates that the softer the material, the "blunter" the tool, the reason being that in soft materials the tool acts with a scraping rather than a cutting action. This prevents the nose of the tool from digging in and producing chatter marks on the work. The cutting angle

Material	Clear-ance Angle	Top Rake	Side Rake
Brass	3 deg.	5 deg.	5 deg.
Cast Iron	3 deg.	10 deg.	10 deg.
Steel	3 deg.	15 deg.	20 deg.

has an important effect on tool life, as well as on the power needed to drive the machine (Fig. 2). See CUTTING SPEED.

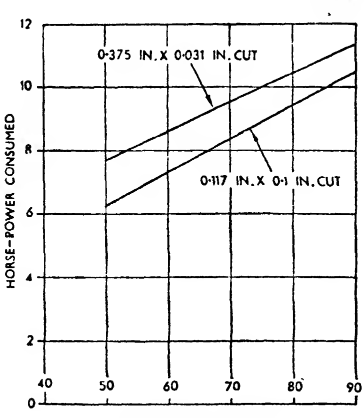


Fig. 2. In this graph, which compares cutting angle and power needed to drive the machine, curves showing horse-power consumed are based on a cutting speed of 100 feet per minute.

CUTTING FLUID. A stream of liquid directed on to the point at which cutting takes place to aid in dissipating the large amount of heat generated when metal is removed from the workpiece by cutting tools. The fluid, sometimes referred to as the coolant, is generally a mixture of soda, soft soap and mineral oils, mixed with water into an emulsion. Where a large quantity is required, the used cutting fluid is collected in a sump,

strained, and pumped back to the point required by means of a small centrifugal pump connected to the driving shaft of the machine.

CUTTING SPEED. The speed at which the work is fed to a cutting tool, whether in a lathe, drilling machine or machine saw. The speed of the feed, in its relationship to depth or area of cut, is one of the factors governing the life of cutting tools; owing, however, to the other factors involved, such as the physical properties of the tool and of the material, rigidity of the work, the shape of the cutting tool and nature of the coolant, it has been found very difficult to establish a specific relationship between the cutting speed and the area of cut for a given tool life.

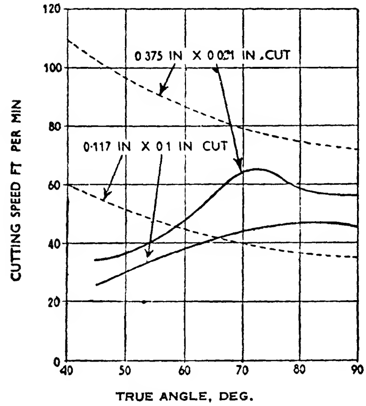


Fig. 1. From the above graph it will be seen that, with a comparatively deep cut the best true angle is 73 deg.

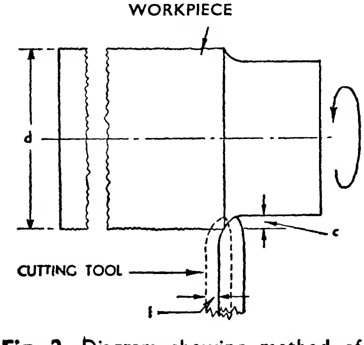


Fig. 2. Diagram showing method of calculating cutting speed for lathes.

Fig. 1 shows how the cutting speed is related to the cutting angle, the full lines referring to the true angle and the dotted to the plan angle. For a given area of cut, however, more metal can usually be removed in a given time by using a deep cut with a fine feed than a shallow cut with a coarse feed.

For lathes, the cutting speed in Fig. 2 is given by the formula πdn, where d equals the diameter of the workpiece and n the r.p.m; the area of cut is given by cf, where c equals the depth of the cut and f the feed or traverse of the tool during one complete revolution. See CUTTING ANGLE.

CYANOGEN, see COAL.

CYCLE. A complete series of events or operations in which conditions at the end are the same as at the beginning of the series. A succession of operations of this kind is usually, though not necessarily, recurrent. In two-stroke internal-combustion engines, for instance, the complete cycle of operations is performed when the piston has completed two strokes in the cylinder and has returned to the position, in relation to the cylinder ports etc., which it held at the commencement, the procedure then being repeated.

In electrical engineering, a cycle can be defined as the complete series of changes that takes place in the value of a recurring variable quantity in the time between recurrences which are identical in magnitude, sign and direction of change. See ALTERNATING CURRENT.

CYCLOIDAL GEAR TEETH. Teeth on gear-wheels in which the tooth profile is generated by an epicycloid curve above or outside the pitch circle, and by a hypocycloid curve below the pitch circle. This form of gear tooth was developed with the object of avoiding interference of the teeth; it has the disadvantage that, for correct meshing, the pitch circles must always remain

exactly tangential. As a result, the distance between the centres of the wheels in mesh must be most accurately determined and must not vary during running. Hence the gear is unsuitable for heavy work and has been chiefly confined to light mechanisms, especially those involving cast gears. For cut gearing and most cast gearing, cycloidal gears have now been superseded by the involute form, which will permit of slight variations in the centre distance without impairing the smoothness of the running.

Geometrically, the use of cycloidal curves for gear teeth was developed as follows:

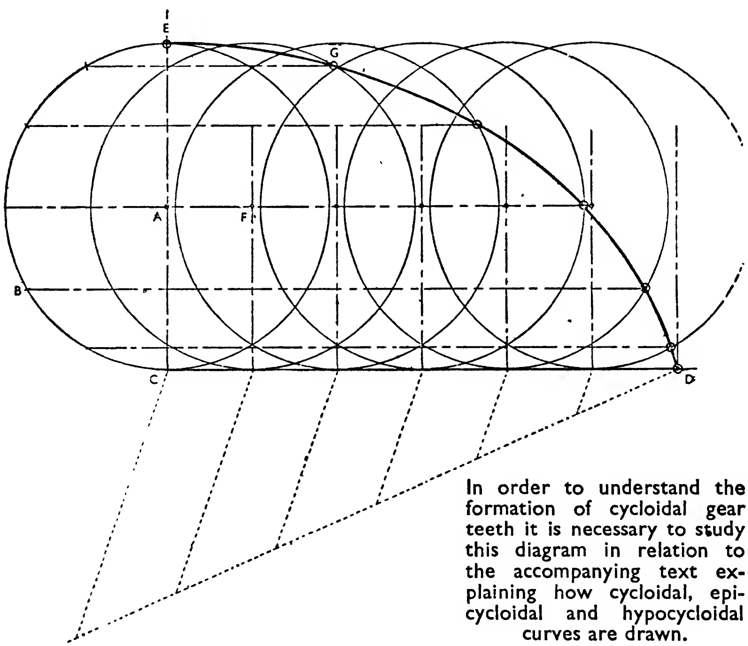
When two wheels are in gear, their pitch circles touch on the line joining their centres. For a constant velocity ratio, the common perpendicular to the two teeth at the point of contact must pass through the pitch point, or point where the two pitch circles touch.

This condition is satisfied when the profiles of the teeth are (a) cycloidal, (b) involute. See INVOLUTE GEAR TEETH.

A *cycloid* is the path traced out by a point on the circumference of a circle when the circle rolls along a straight line.

An *epicycloid* is the path traced out by a point on the circumference of a circle when the circle rolls on the outside of the circumference of another circle.

A *hypocycloid*, however, is the path traced out when the rolling circle rolls on the inside of the circumference of another circle.



In order to understand the formation of cycloidal gear teeth it is necessary to study this diagram in relation to the accompanying text explaining how cycloidal, epicycloidal and hypocycloidal curves are drawn.

The construction of a cycloid curve is shown in the accompanying diagram. With centre A and desired radius AB; draw a circle. Let CE be vertical through centre A. Draw a tangent CD, of length equal to half the circumference of the circle. (This must be done by multiplying radius AB by 1·57, and measuring off that amount, as there is no geometrical construction for it.) Then divide CD into, say, 6 equal parts (this can be

done by the well-known "similar triangles" method) and also divide the corresponding half-circumference of the circle BCE into 6 equal parts. Then draw vertical lines through each division of CD and where each one cuts the horizontal through A (e.g. at F), draw a circle of radius AB.

Now when circle BCE has rolled over one division (one-sixth) of CD, the original radius AE will have taken up new position FG. Then EG is the first portion of the cycloid curve. Similarly, other circles, all of radius AE = FG etc., are drawn, and a series of points obtained. A fair line is drawn through them to give the cycloidal curve ED, which is of course only one-half of the entire cycloid, the other portion being the mirror image of it.

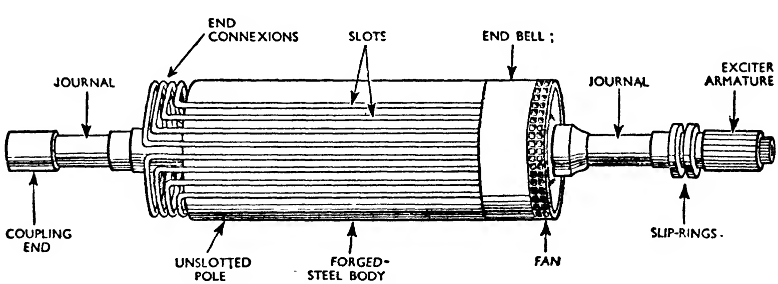
The construction of epicycloids and hypocycloids is similar, but in those cases CD instead of being a straight line, is a circular arc, being part of the circumference of the rolled circle. The rolling circle BCE is divided up as before.

CYLINDER. A chamber of tubular shape in which the piston of an engine or the plunger of a pump travels to and fro. In an internal-combustion engine, the part of the cylinder which is beyond the limit of the piston's travel forms the combustion chamber. Automobile engines may have one, two, four, six, eight or twelve cylinders arranged in different ways. Aeroplane engines, if air-cooled, may have up to eighteen cylinders arranged radially in two rows, or up to nine cylinders in a single radial row. Liquid-cooled aero engines may contain two or more "banks" of up to six cylinders arranged in line so that they are V, H or X in section.

The cylinders in a four- or six-cylinder motor-car engine are placed side by side and cast all in one block (see MONOBLOC). The cylinder assembly is in two main parts: the cylinder casting, machined perfectly smooth and flat on its upper surface, and the cylinder head or cover, machined on its under surface. The cylinder head is secured to the casting or block by nuts and studs screwed into the block with a jointing medium, termed a gasket, between them. Removal of the cylinder head exposes the piston crowns, cylinder bores and valves. Poppet valves may be accommodated in the block, when they are known as side valves, or in the head, being then termed overhead valves.

CYLINDER MACHINE, see PRINTING MACHINES.

CYLINDRICAL ROTOR. A rotor for an electrical machine which is made from one or more forgings and not built up from laminations. Slots are machined as required. This construction is used in large high-speed machines such as turbo-alternators. The diagram below shows the general appearance. See ROTOR



ELECTRICAL MACHINE ROTOR

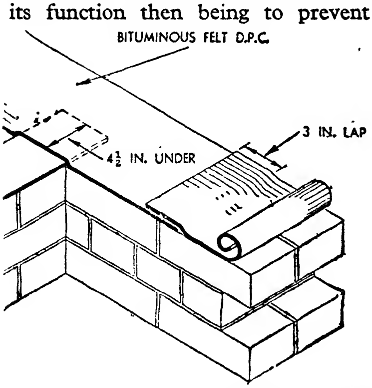
In this rotor for a turbo-alternator, end bell and other supports for the end connexions are omitted at left-hand end to show how the windings are arranged. Rotors such as that shown in this diagram have two poles and run at 3000 r.p.m.

DAMPED OSCILLATIONS. Oscillations which diminish in amplitude, the decrease generally following a logarithmic law. Damping, intentional or otherwise, is due chiefly to resistance and losses occasioned by radiation.

DAMPING. The action of forces or moments which tend to reduce the magnitude of an oscillating or vibrating motion. In aeronautics, the most common application of the term is in connexion with stability problems.

DAMPING WINDING. A short-circuited winding in an electrical machine used for suppressing fluctuations in speed. It may take the form of a metal grid in the pole face. Eddy currents in the damping winding produce a torque which opposes the change in speed. Synonym: Amortisseur. See HUNTING.

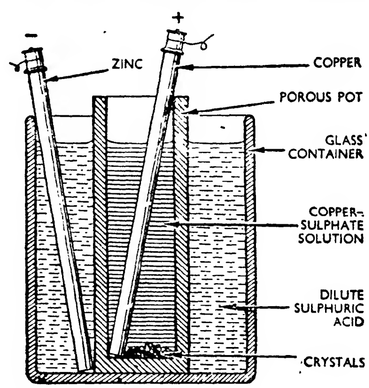
DAMP-PROOF COURSE (D.P.C.). A layer of impervious material laid throughout the entire length and thickness of walls of buildings. The course should be made continuous and unbroken irrespective of the changes in the level occasioned by rising and falling ground. When situated at the base of a wall, it should be placed about 6 in. above ground level and below ground-floor level, its function then being to prevent damp from the ground rising into the floors through the walls, and to keep the interior dry.



Damp-proof courses are laid through length and thickness of a wall, as is this one of the bituminous-felt type.

Damp-proof courses may be formed of any of the following materials:—(a) two courses of slates, half-lapped at joints, and bedded in cement mortar; (b) sheets of lead; (c) bituminous felt having a lead core; (d) asphalt and (e) vitrified bricks or tiles.

DANIELL CELL. A primary electric cell which employs copper and zinc electrodes. There are two electrolytes separated by a porous pot or similar device. The diagram shows the usual form of Daniell cell.

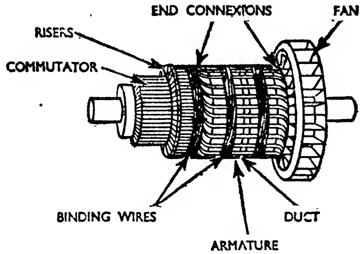


Common form of Daniell cell, which has an e.m.f. of 1·1 volt. The copper-sulphate crystals in the inner container keep the solution saturated.

DARKENING OF PAINT. All paints containing lead darken upon exposure to sulphur fumes. In the atmosphere of large towns, such fumes are always present and disfigurement is liable to occur. This does not mean that the film has lost its weather-resisting properties, but that it has changed its colour and lost its aesthetic value.

D.C. Abbreviation for DIRECT CURRENT (q.v.).

D.C. GENERATOR. D.C. generators and alternators are essentially



View of a D.C. armature showing how the coils and end connexions are held in place by binding wires. The fan is to aid cooling, a purpose also served by ducts, one of which is shown.

similar in many respects. The same methods of construction are used and many electrical and mechanical features are common to both machines. The main difference is that the D.C. machine has a commutator and that the rotating member is always the armature. A D.C. armature and commutator are shown in the accompanying illustration.

The e.m.f., as it is generated, is alternating in character just as in the alternator. A D.C. armature possesses at least two circuits and connexions are so arranged that a particular conductor is automatically transferred from one circuit to another at the time when the e.m.f. generated in it is nothing.

This switching operation is performed by the commutator, which consists of a large number of copper segments, insulated from one another and connected to points distributed round the winding. The winding is closed upon itself but this does not involve a short-circuit, because the e.m.fs. in the two halves are equal and opposite.

Brushes, bearing on the commutator in suitable positions, tap the winding at points where the e.m.f. changes sign, so that, as far as the external circuit is concerned, the two or more parts of the armature winding are in parallel.

Although the conductors rotate, the points at which the e.m.f. changes sign are stationary in space, the conductors taking it in turn to fulfil the role.

A D.C. generator may be separately excited, as in the case of the alternator, or it may be self-excited, that is to say, it generates its own field current. Self-excitation is not possible unless there is some residual magnetism (q.v.) in the field, and unless the connexions are so arranged that the e.m.f. thus produced assists the residual magnetism to increase. In addition, the field-circuit resistance must not be too high, nor the speed too low. The field connexions may be shunt, series, or compound, as in the case of D.C. motors (see COMPOUND WINDING).

The e.m.f. is proportional to speed and flux, and the latter is varied by altering the field current. This may be done by use of a variable resistance known as a field regulator.

One of the important problems encountered in D.C. generators is that of commutation. As mentioned earlier, a conductor passes from one circuit to another as the commutator segment, to which it is connected, passes under a brush. When this happens the direction of the current must reverse and the reversal must take place in the very short time during which the conductor or coil is short-circuited by the brush. Owing to the inductance of the coil it is not often possible for the reversal to occur quickly enough without some assistance in the form of an e.m.f. which is injected into the coil while it is short-circuited.

The injected e.m.f. is generally obtained by arranging for the coils to be in a magnetic field produced by interpoles at the time when the e.m.f. is needed (see COMMUTATING POLE). The interpoles carry a series winding so that the amount of e.m.f. injected varies with the load current and in this way sparkless commutation is achieved at all loads.

For particulars of the somewhat specialized type of generator used in motor vehicles, see DYNAMO.

DEAD-BEAT. An electrical instrument, or other device, is dead-beat

when it is designed so that the pointer swings to a reading without any appreciable overshooting, and, on the other hand, is not sluggish. It is generally desirable, however, that the pointer should swing once slightly beyond its final position because this indicates that it is not sticking. It is then no longer dead-beat but is under-damped.

DECALCOMANIE PROCESS. A method of producing transfers of coats of arms, trademarks and like matter for application to wood, glass, metal, bicycles, sewing machines etc., where the design cannot be directly printed in the usual way.

Paper is specially coated with gum or glue, starch and flake white or talc. The image appears reversed on the transfer so as to read correctly when in final position. Also, the colours are printed in opposite order from the usual sequence and, finally, overprinted in white. When the image is transferred, white forms the base and the rest of the colours appear normal.

These transfers are usually produced lithographically, mainly by direct lithography, but a limited use has recently been made of the gravure process.

DECALESCENCE POINT, see HARDNESS.

DECARBONIZING. The removal of carbon deposits from the cylinders, valve ports, pistons, valves etc. of an internal-combustion engine. This carbon is the residue from the burnt gases and oil. If allowed to remain, the carbon particles form hard nodules which may become incandescent during the explosion period and cause pre-ignition, overheating and engine-knock.

To decarbonize an engine, remove the cylinder head and valves, then scrape the affected parts with a blunt scraper, taking care, especially where alluminium-alloy pistons and cylinder heads are involved, not to scar the smooth metal. There is less likelihood of subsequent rapid carbon formation if the surfaces are left smooth.

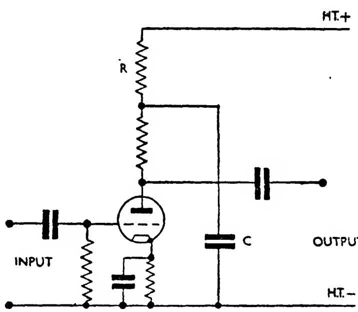
DECIBEL. A logarithmic measure of ratios, used principally in electrical communication to express gains and losses of power. Two quantities differ by 1 decibel if their ratio is 1·259, or in general, db (decibels) $=$ 10 $\log_{10}$ (ratio).

The decibel is one-tenth of a bel and it cannot be used as an absolute measure unless a reference point is specified or assumed.

DECKING. The upper surface of a flying-boat hull; also the top covering of a landplane fuselage, unless this is of monocoque (q.v.) construction.

DECLARED EFFICIENCY. The efficiency of an electrical machine determined in a manner prescribed by a British Standard Specification. See EFFICIENCY.

DECOUPLING. A system of overcoming unwanted regeneration, oscillation or degeneration, due to a



Circuit diagram showing decoupling components used for valve amplifiers.

common impedance in D.C. supply sources for anode and grid circuits of valve amplifiers.

A common impedance, however, tends to couple together all its associated circuits and may in certain circumstances set up instability.

In the accompanying diagram, the resistance R is included in the anode supply of the valve and the condenser C is connected to the H.T. negative. The reactance of C must be low compared with the resistance of R, and they jointly form a simple A.C. potential dividing-network which causes the unwanted variation of supply voltage to appear across R, where it does not matter, rather than

across C, where it would be directly in the anode load circuit.

DEDENDUM, see SPUR GEAR.

DEEP ETCH. An image printed by the normal lithographic process on to a zinc plate, the "depth" varying from a simple local chemical cleansing of the image surface to a biting of the metal to a depth of, say 0·001 in. The advantages of this type of image bear no relationship to its depth. Deep-etch images, or offset-deep images, as they are sometimes known, are less simple to produce than either a printed-down (photo-litho albumen) or a transferred image but, when skilfully made, are superior in working and lasting properties, in the excellence of half-tone dot formation and in graded-tone production. The profusion of named processes indicates the number of possible variations in manipulation and materials, but most methods conform to general principles.

A positive photographic image is printed-down to a litho metal plate, thus forming a negative mask. This mask or stencil is temporary; it is therefore sufficiently durable to withstand the required manipulation, but is readily and completely removable when the positive image has been established. Such stencils are usually formed in bichromated gum, glue casein or synthetic material. This film may be stained to assist visible control.

Development in water or alcohol clears the areas for the positive image, and these areas may be etched with a suitable acid solution to make them lithographically clean and image-receptive; the action may be continued to "lay deep" the image. All parts of the plate which are not to be etched are stopped out with a suitable ground. Image-forming ink is then applied to the cleaned areas, but more usually an ink-attracting resinous base is first rubbed-in as foundation for the ink. The stencil is then carefully and thoroughly removed and the plate prepared for printing.

Deep etch by electro-deposition (q.v.) is a satisfactory, but less frequently used, method. In this, a printing plate is given a slightly roughened surface by either mechanical or chemical means, coated with light-sensitive solution, exposed to a photographic negative, and inked and developed in the usual way. The plate is then placed in a depositing tank, and metal is built-up round the image electrolytically.

The deposited metal may be harder than the base, thus making a more durable plate. A feature is that, as the surface wears, through long machine service, further deposit can be "grown", thus considerably extending the life of the plate. The deposited metal has remarkable water-retaining and ink-rejecting properties, and the use of gum arabic is unnecessary.

DEGENERATION. The opposite of reaction. An effect occurring in an electric amplifier when part of the output is fed back to an earlier part of the circuit and there opposes or weakens the original signal voltage. Also called negative feed-back (q.v.).

DE-GREASING (Metallurgy). The removal of grease and oily contamination from metal articles, usually before some finishing operation such as tinning or painting. A de-greasant, consisting of a solution, in water, of between 1 and 10 per cent concentration, is utilized and may be applied by spraying, dormant immersion, electrolytic immersion or "barrelling."

The best general method makes use of the trichlorethylene de-greasing plant, in which the components to be de-greased are immersed in a specially designed container filled with the vapour of trichlorethylene. The solvent condenses on the cold metal and effectively dissolves the grease and oil. Trichlorethylene does not, however, dissolve soaps, which are often ingredients of drawing and polishing compositions. In such cases immersion in the boiling solvent is desirable, as the liquor's scrubbing action promotes removal of the contaminants.

De-greasing can also be carried out by means of hot or boiling solutions of alkalis. The parts to be de-greased are often made the cathode

in a hot alkaline solution, and a potential of about 12 volts is applied. The gas generated at the metal surface breaks-up the oily film, and very rapid and thorough de-greasing is effected. The electrolytic method is especially suitable for de-greasing before electro-plating. See ELECTROLYTIC CLEANING.

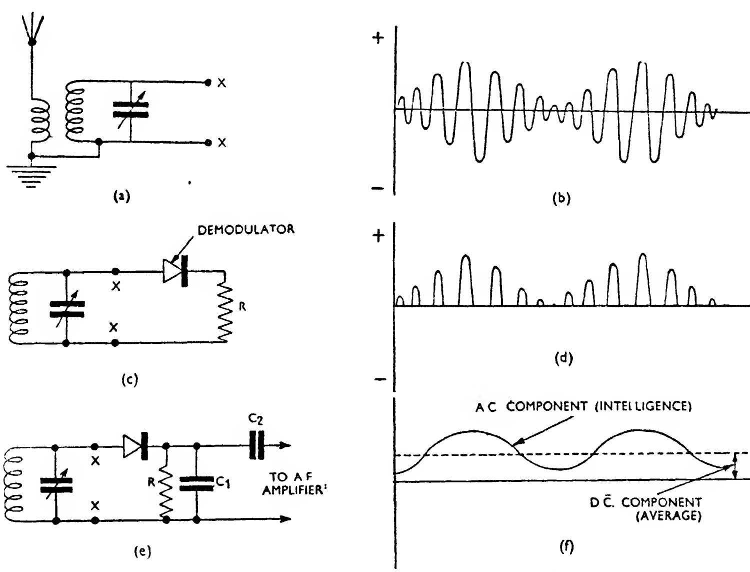
DEHYDRATION. The removal of water from a substance; dehydration is most common in foodstuffs, to save weight and space in transport and to prevent decay. If the foodstuff is already semi-liquid, it may be dehydrated by forcing it on to a metal surface kept at a suitable temperature. If it is a solid substance it is cut into thin slices or small fragments and heated.

DELIQUESCENCE. The capacity of a compound to absorb moisture from the atmosphere and then dissolve in the water it has absorbed. Table salt and magnesium chloride are deliquescent substances.

DELTA CONNEXION. A method of connecting three-phase electrical apparatus or machinery to form a closed circuit. Synonym: Mesh Connexion. See ALTERNATING CURRENT.

DEMAND FACTOR. The actual maximum demand made by a group of consumers of electricity, divided by the demand which would occur if every piece of apparatus were in use simultaneously. Compare with diversity factor.

DEMODULATION. In radio reception, the process of extracting the intelligence, for example, speech or music, from the modulated high-frequency carrier wave. Across the tuned circuit in a receiver, the



BASIC PRINCIPLES OF DEMODULATION

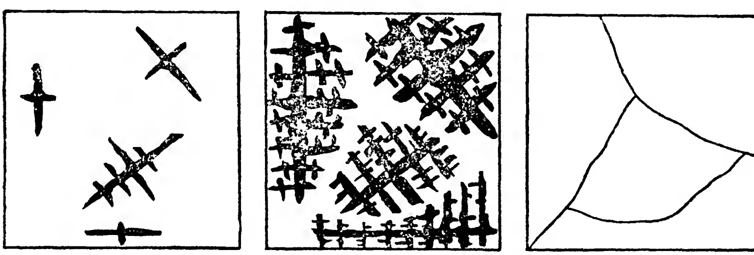
Shown above are (a) pre-selector circuit; (b) wave-form of an amplitude-modulated signal appearing across points x-x prior to demodulation; (c) the demodulator, a crystal or diode, and load resistance R added ; and (d) uni-directional voltage across R. The other two diagrams show (e) the inclusion of condenser C_1 to remove R.F. "ripple" and (f) demodulated output consisting of fluctuating uni-directional voltage, the A.C. component of which represents the intelligence and is separated from the D.C. component by condenser C_2.

programme-modulated carrier wave sets up voltages which are an exact but weak duplicate of those at the transmitting aerial.

If a pair of head telephones were connected directly across such a circuit, no sound would be heard because the frequency of the alternations would be too high and the average current through the phones would be zero. However, if the voltage could be made uni-directional, the telephone diaphragm, while not being able to follow the individual high-frequency alternations, would rise and fall at a rate determined by their change of amplitude.

To change the alternating current into a uni-directional one, it becomes necessary to insert some device capable of conducting in one direction, but not in the other. It is this device which is called a demodulator. Various arrangements may be used, for example, certain crystals, thermionic diodes, triodes etc.

DENDRITE. The crystal skeleton which is formed initially during the solidification of a metal. A dendrite starts from a nucleus by throwing out an arm from which other arms grow at right-angles. Still others grow as shown in the diagram which indicates the various stages in the formation of a crystal grain. Simultaneously with the growth in length of the dendritic arms, a thickening occurs until the entire crystal grain is solid. Dendritic structures can often be observed under the microscope in the case of binary alloys, but not with pure metals. See CRYSTAL GRAIN and CORED STRUCTURE.



FORMATION OF CRYSTAL GRAINS

Diagram showing nucleus from which a dendrite commences by throwing out arms at right-angles; others grow from these. Entire solidification eventually occurs.

DENSENER (Metallurgy), see CHILL.

DEPOLARIZATION. The removal of those reaction products, such as hydrogen, in an electric primary cell, which cause an increase in the internal resistance. In an ordinary battery, manganese dioxide is packed round the carbon electrode to act as a depolarizer. See PRIMARY CELL.

DEPRESSION, see FREEZING-POINT.

DEPTH GAUGE, see HEIGHT GAUGE.

DETECTOR. An older name for demodulator. See DEMODULATION.

DETERGENT. A cleansing material which may act in one or more of the following ways: (1) by solvent action on the unwanted matter; (2) by penetration by surface activity between the two materials; (3) by chemical decomposition of the unwanted material; (4) by chemical or electrical action on the body to be cleaned to produce gaseous products at the surface, which remove the unwanted matter.

Water alone can act as a detergent by the first two methods, but rarely does so by the third. Solvent action may be improved by adding materials such as alkalis (e.g., caustic soda, soda ash, sodium silicates, sodium phosphates etc.).

To assist penetration the addition of surface-active agents such as soaps, alkyl sulphates, sulphonates etc., is

required. Other secondary factors which require consideration are the nature of the rinse water, temperature, conductivity, action on the surface to be cleaned etc., and compounded detergents usually take into consideration all of these factors. See DEGREASING.

DETONATION (Auto. Engineering). The extremely rapid combustion of the mixture of air and fuel-vapour in the cylinders of an internal-combustion engine of the petrol or paraffin type.

This causes an instantaneous thrust on the piston, as opposed to gradual expansion of the gases under normal conditions, and gives rise to a distinctive knock, or "pinking" sound, in the engine. Detonation is influenced by the use of unsuitable fuels, high compression ratio and by the position and type of sparking plugs fitted; it causes overheating and loss of efficiency.

DEUTERIUM (D). Atomic no. 1; atomic wt. 2·013; an isotope of ordinary hydrogen; it combines with oxygen to form deuterium oxide, or heavy water, D_2O.

DEXTRINE. An adhesive, prepared from starch, and sometimes known as *British gum*. It is obtained in the form of a dry, soft powder which, on admixture with cold water, forms a paste of exceptional adhesive properties.

Dextrine is used in paperhanging (q.v.), for the application of embossed and relief materials. The paste should be made the day before use, and should be well brushed into the fabric and not left in excessive quantity as a film.

D.F., see DIRECTION-FINDING.

DIALYSIS. Separation of a mixture of water-soluble crystals and of colloidal solids by placing them in a bag of parchment or some similar type of membrane and suspending the bag in a stream of water. The soluble salts will pass through the fine pores of the membrane, while the colloidal solids, which are larger in size, remain behind.

DIAL GAUGE, see CLOCK GAUGE.

DIAMAGNETIC. The magnetic quality of a substance which has a fractional permeability (q.v.). Antimony and bismuth are among the few diamagnetic substances.

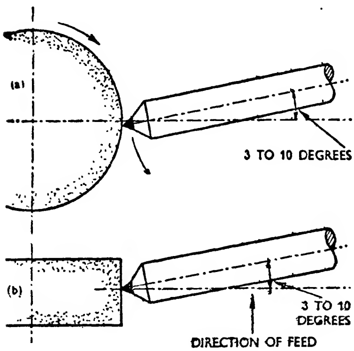
DIAMETRAL PITCH. The ratio of the number of teeth on a wheel to the diameter, in inches, of the pitch circle of the wheel. This figure furnishes a useful comparative dimension for the size of teeth of cut gearing. If the diametral pitch is 5, there will be 5 teeth on the periphery of the wheel for every inch of pitch-circle diameter; a diametral pitch of 5 would thus fix the number of teeth at 60 for a 12-in. pitch circle.

The method of using diametral pitch has been adapted to the institution of a regular system of tooth proportions and sizes. Following the example given, the pitch diameter will be $12\frac{1}{5}$ in. for 61 teeth, $12\frac{2}{5}$ in. for 62 teeth, $12\frac{3}{5}$ in. for 63 teeth and so on. The distance between the centres of two gear-wheels in mesh is given by the number of teeth in the two wheels divided by twice the diametral pitch.

Normally, diametral pitches of the following range are used: 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2, $2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{3}{4}$, 3, $3\frac{1}{2}$, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18 and 20. By keeping to these numbers and avoiding other fractions, gears and gear cutters can be standardized, with resulting advantages in manufacture.

DIAMOND. A crystalline form of carbon, one of the hardest substances known. In the diamond each carbon atom is linked to four other atoms placed symmetrically round the first atom. Diamonds are used not only as gems: imperfect or badly coloured diamonds are used as abrasives and in drills for cutting purposes. See DIAMOND TOOLS.

DIAMOND TOOLS. Owing to its hardness and wear-resisting qualities diamond (q.v.) is used on tools or in crushed form as diamond powder. Colourless (blue-white) or slightly yellow diamonds are in demand as gems, and usually cut as "brilliants", but about 75 per cent of the world's diamond production by weight is to-day used for industrial purposes;



Method of using diamonds to true-up grinding wheels. The diamond, inclined to the horizontal, may contact the wheel below the centre line, as in (a) or, alternatively, (b), it can be inclined to the axis of the wheel.

these diamonds may be off-colour and may have some imperfections.

Modern industry uses the diamond in various forms. Rough diamonds set into metal holders serve as truing tools for grinding wheels, or numerous diamonds set on the end of a tubular holder form a drilling crown for deep drilling and exploration drilling. Rough diamonds are also used in stone saws, as glass cutters (glaziers' diamonds), for dentists' drills and for engraving purposes.

Shaped-diamond tools with cutting edges which are highly polished, similar to the surfaces of ornamental stones, serve for fine turning and boring various kinds of metals and non-metallic materials and for truing fine-grained thread grinding wheels. They are also used as hardness indenters and as diamond dies.

Diamond powders, made from impure diamonds (i.e. boart) and broken pieces are embedded in metals or plastics and used as grinding and polishing tools for hard materials, in particular ceramics and sintered carbides. Diamond dust itself is used as an abrasive.

The illustration shows a diamond tool for precision truing of grinding wheels. It will be noticed that the holder is approached under a drag-angle and the diamond tip contacts the grinding wheel on, or slightly below, the centre line.

DIBASIC ACID. An acid that has two hydrogen atoms which can be replaced by such a metal as sodium or potassium. Sulphuric acid, H_2SO_4, is an example, and it can form both sodium acid sulphate, $NaHSO_4$, and sodium sulphate, Na_2SO_4.

DIE. The supporting, cutting or shaping unit of a press tool, having an opening or cavities, and used in conjunction with a punch to produce shapes in sheet metal, or for coining or embossing heavier material.

Blanking dies (Fig. 1) are used to cut plain flat pieces of stock, often without perforations, while drawing dies produce cylindrical or cup-shaped work from flat material. The die is a fixture on the table, or sometimes on the ram of the press, and usually has a stripper plate (Fig. 2) or pins to pull the work off the punch as it ascends. The die is invariably wedge-shaped as shown, to provide clearance for the blank passing through the die. The stripper plate may also be a guide for the stock, to locate it directly under the punch as the operator or the machine feeds it forward.

More elaborate dies allow for a triple action of blanking, drawing or embossing; or where a large number of similar parts are required, gang or multiple dies with many similar

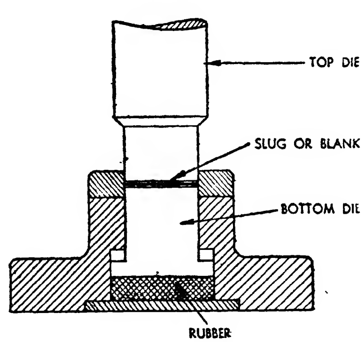


Fig. 1. Slugs, or blanking dies, are used as shown, to cut flat sheet metal.

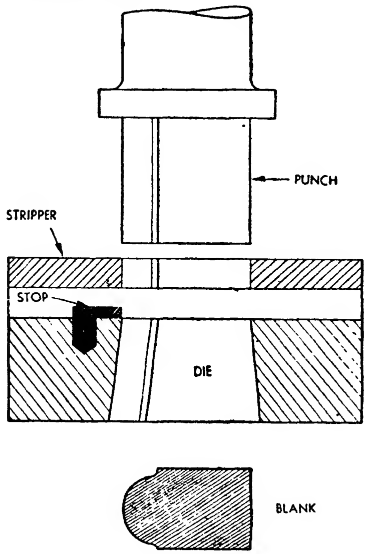


Fig. 2. Stripper plates are provided on die presses to remove the work-piece from the punch as it rises.

openings allow duplicate punches to cut several blanks at each stroke.

DIE CASTING. A casting made by pouring molten metal into a permanent metal mould or die. The process of making a casting in this way is known as die-casting. The initial cost of moulds, or dies as they are more generally known, is much greater than that of ordinary sand moulds; but since one die can be used for making many castings, the cost per casting is generally lower.

Two distinct processes, known as *gravity* and *pressure* die-casting respectively, are used in the manufacture of die castings. In gravity die-casting, the liquid metal is poured into the mould, the casting being fed by the hydrostatic pressure set up by gravity. This process is simple and produces good, clean castings with an accuracy of about ± 0.005 in. per in.

Pressure die-casting requires the use of special and expensive machines for introducing the metal to the moulds and for applying a considerable pressure to the metal as it solidifies. Castings produced by this process are accurate in both shape and dimensions, the accuracy obtainable being 0·001 in. per in. Moreover, the applied pressure effectively prevents the formation of blowholes and other defects.

The maximum size of die casting that can be made by either process is limited both by the great cost of large permanent moulds and the practical difficulties experienced in making large die castings.

DIE CUSHION. A form of shock-absorbing apparatus used in metal-drawing operations to maintain a controllable, but yielding, resistance to the motion of the main drawing die. Die cushions may be simply rubber pads or loaded springs, but pneumatic, as illustrated, or hydraulic devices are more common.

The latter consist of a cylinder (or cylinders) fitted with a piston supporting the bolster plate, while a

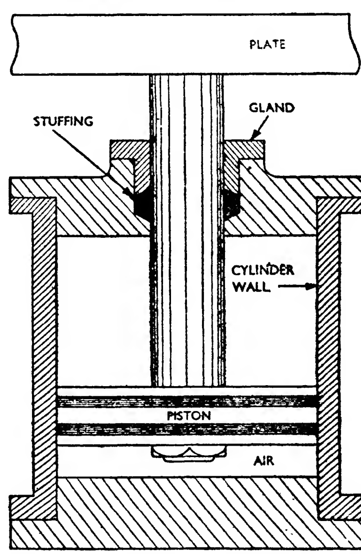


Diagram showing pneumatic die cushion used in metal drawing.

regulator valve allows the correct pressure to be maintained by the working medium, oil or air. The piston usually actuates a pressure

plate, from which pressure pins extend to carry the die structure itself. In operation the piston is actuated before the beginning of the drawing stroke, and thus provides a means for holding the blank firmly at one or more places.

As the drawing operation proceeds the blank slips locally, but under restraint, so that when the draw is completed, wrinkling and tearing, either of which would have been probable without the shock-absorbing element, have been avoided. Further, one operation will often suffice as against several on a press without a cushion.

DIELECTRIC. A material which has a high electrical resistance. As a rule, certain other properties, for example, a low power-factor (q.v.) or a high dielectric-constant (q.v.) are desirable as well. Synonym: Insulating Material. See INSULATOR.

DIELECTRIC CONSTANT. Symbol: κ. The ratio of the capacitance of an electrical condenser when using a given material as the dielectric (q.v.), to that of the same condenser when the dielectric is air. Synonyms: Permittivity, Specific Inductive Capacity. See CAPACITANCE, CONDENSER and DIELECTRIC.

DIELECTRIC HYSTERESIS. An effect which causes the electric flux density in a dielectric to depend on its previous electrical condition as well as upon the electric force at the time. The effect is similar to magnetic hysteresis (q.v.). See ELECTRIC FLUX DENSITY.

DIELECTRIC LOSS. The electrical power loss occurring in a dielectric (q.v.) when it is subject to an alternating electric field. See DIELECTRIC HYSTERESIS.

DIELECTRIC STRENGTH. Synonym for ELECTRIC STRENGTH (q.v.).

DIESEL ENGINE. The name in general use for the compression-ignition (C.I.) engine in which the charge is ignited by compression. See COMPRESSION-IGNITION ENGINE.

DIESEL OIL. A fraction obtained by the distillation of petroleum. It begins to boil at about 170 to 176 deg. C., and half of it distils over below 300 deg. C. It is used as a fuel in compression-ignition engines (q.v.). See FUELS.

DIE SET. A punch holder, die holder, or base complete with guide-pins, for holding the punch holder and die holder correctly in alignment, thus forming a complete unit ready for attachment to the press bed or ram. These standard sets are manufactured in many types and sizes by specialized firms, and the user has only to fit the punches and dies for his particular operation.

The types available include sets with guide-pins at the rear, centrally located where rigidity is the prime consideration, or diagonally spaced as required. Punch and die holders are usually of semi-steel, with hardened and ground guide-pins and bushings with means of lubrication.

DIFFERENTIAL GEAR. A gearing which allows relative rotation of two shafts when driven by a third shaft. Such an arrangement is invariably incorporated in the driving axle—usually the rear axle—of an automobile to enable the driving effort, or torque, to be applied equally to the

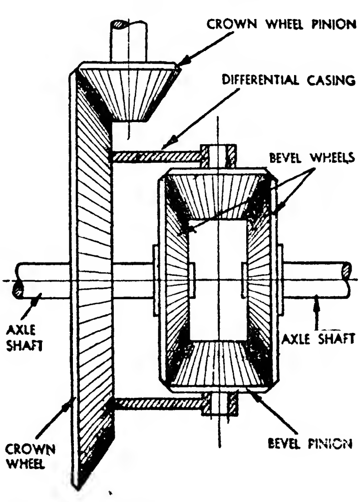


Fig. 1. Main components of a simple differential of the type commonly fitted to present-day road vehicles.

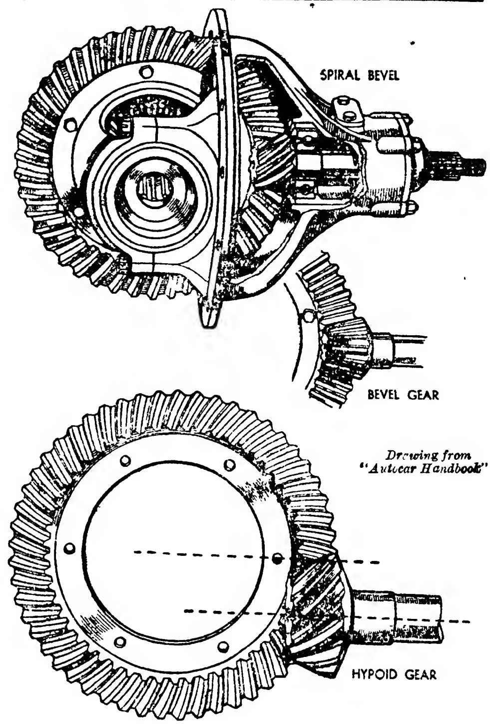


Fig. 2. Examples of three variations of bevel-and-pinion rear-axle drive. The teeth of the spiral bevel and hypoid gears are cut at an angle of 30 deg.

road wheels when the vehicle is cornering and the outside wheel has to turn at a greater speed than the inner one. Two separate axle shafts are coupled together by the differential gearing mounted within a casing secured at the centre of the crown wheel or worm wheel of the final drive.

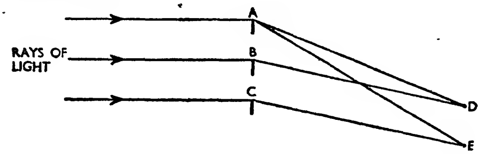
A simple type of differential gear is illustrated in Fig. 1. A bevel or sun wheel is secured at the end of each axle shaft; these two bevels are connected by four smaller planet bevel pinions pivoting on spindles held in position by the two halves of the differential casing. A *bevel gear*, shown in Fig. 2, consists of two straight or spiral-toothed cone-shaped wheels, known as the crown wheel and pinion respectively, which engage one another. The crown wheel has more teeth than the pinion. After a period of service this gear, though efficient, tends to become noisy due to the teeth losing their form.

The *spiral bevel and hypoid gear* is similar to the bevel gear in design but the teeth of the wheels are cut at an angle of 30 deg. thus giving an overlapping tooth action. In the hypoid gear, also shown in Fig. 2, the pinion is placed below the centre line of the crown wheel, the sliding action thus obtained enabling a smaller crown wheel and pinion to be used. These gears are stronger and more silent than the straight bevel.

As torque is applied to the driving bevel pinion, the crown wheel rotates and with it the differential assembly. When the resistance offered to each axle shaft is equal, as when the vehicle is travelling straight ahead, the differential pinions remain stationary on their spindles and act as a wedge between the two axle bevels. When cornering, greater resistance is offered by the inside shaft, causing the bevel pinions to rotate and the speed lost by the inner is taken up by the outer wheel without slip or skidding of either.

DIFFRACTION. Dispersal of light at the edges of a shadow, caused by the interference of light waves with each other, which is complete in some places and partial in others. If the light is a mixture of light of different colours (ordinary white light), the diffraction fringes are coloured, each fringe being blue on the side next to the shadow and red on the far side.

Diffraction of light can also be effected by ruling fine parallel lines on glass to form a "grating" that is either transparent or reflecting. The



Diffraction of light takes place at the edge of a shadow and alternate light and dark patches occur parallel to the shadow, as shown at D and E.

passage of X-rays or electrons through a solid body may also cause diffraction patterns owing to interference of the waves, and in this way knowledge has been gained of the arrangement of the atoms of the solid.

In the accompanying diagram, ABC represents a side view of three lines. Light rays approaching from the left are bent as shown, striking against a screen at DE. Distance AD is exactly half a wavelength longer than distance BD, and this leads to darkness at D. Distance AE is a whole wavelength longer than CE, there is no interference, and E is a bright spot.

DIFFUSION. The spreading of molecules or particles, tending towards uniformity. In a gas, or mixture of gases, the molecules are capable of rapid movement. In a mixture of liquids the molecules are capable of a slower movement. The result of such movement is that gradually the composition of the mixture becomes quite uniform. A smaller and slower movement takes place in some solid bodies; if a flat bar of gold is placed on a flat bar of lead, the lead will slowly permeate for a short distance into the solid gold, and a little of the gold will gradually penetrate into the lead. A similar diffusion takes place when nickel is deposited on iron.

DIHEDRAL ANGLE. The angle at which the wings of an aircraft are tilted—slightly upwards from the horizontal, as shown in the illustration—to provide stability about the rolling axis. This angle is greater for low-wing than for high-wing machines, but rarely exceeds 6 deg. It is sometimes referred to as *lateral* dihedral to distinguish it from *longitudinal* dihedral, the angle between the chords of the main and tail planes.

DILUENTS. Liquids added to paint, varnish or distemper for the purpose of thinning in order that the material may be easily distributed as a film of even thickness; having performed that function they are no longer required and should dry out. Those in ordinary use are water, genuine turpentine, white spirit and commercial alcohol. Water used for the dilution of distempers must be clean and free from alkaline or acid contamination. For oil painting the turpentine should be of fairly recent distillation and free from any resinous accumulation; the product of oxidation. White spirit should not contain any trace of non-drying mineral oil.

Although these form an integral part of flat finishes, gloss paints, varnishes and enamels, they must never be added to the finished product; as their slightly solvent action is insufficient to obtain a satisfactory blending, an indifferent finish will result. Commercial alcohol is used for the dilution of knotting (q.v.) and spirit varnishes. Complex forms of alcohol are used for the dilution of cellulose finishes.

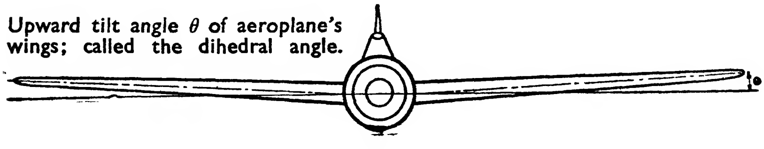
DIODE. A two-electrode thermionic radio valve comprising an anode and a cathode. See RADIO VALVE.

DIP BRAZING, see BRAZING.

DIPOLE. A half-wave aerial, connexions to which are made at the centre. See AERIAL.

DIRECT COUPLING. A term applied to a radio amplifier in which the grid of a valve receiving an output

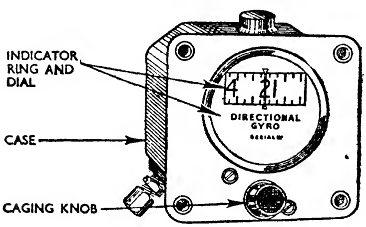
Upward tilt angle θ of aeroplane's wings; called the dihedral angle.



voltage is directly connected to the anode of the valve providing it. Such an arrangement is capable of amplifying direct voltages as well as alternating voltages.

DIRECT CURRENT. An electric current which is substantially constant in value and which flows in only one direction.

DIRECTIONAL GYRO. An instrument developed by the Sperry Co. to indicate any deviation from a set



Directional gyro as fitted to aircraft; used in conjunction with a magnetic compass to indicate to the pilot any deviation from a set course.

course. It responds more rapidly to changes of direction than the magnetic compass, and so enables the pilot of an aircraft quickly to check deviations from course. The instrument illustrated contains a gyroscope which is kept spinning about a horizontal axis by a jet of air induced by the suction of the vacuum pump or venturi tube.

A circular scale calibrated from 0 deg. to 360 deg. is attached to the gymbal rings containing the gyro, and a segment of this scale is visible to the pilot through the glass front of the instrument case, on which a vertical lubber line is marked. When the aircraft turns, the gyro and the scale remain fixed in space while the aircraft and case move round them, thus showing the pilot relative movement between the scale and the lubber line.

DIRECTIONALITY. Variation in the physical properties of metal with reference to a particular direction, usually that in which it is worked. This results in uneven flow of the sheet during forming operations, and may cause splitting and "ears" in drawn work. Causes of directionality include: (a) segregated impurities which are rolled out into threads or planes. (b) elongation of the crystals in the direction of rolling or (c) non-uniform crystal-size with planes or "stringers" of small crystals possessing low ductility.

Careful annealing does not always ensure uniform recrystallization; it is advisable to test samples of sheet for directionality by micro-examination and a tear-length test, which shows the direction in which the metal tears most freely.

DIRECTIONAL STABILITY, see LATERAL STABILITY.

DIRECTION-FINDING. Taking bearings by means of radio. The basis of direction-finding (D.F.) for ships and aircraft is the frame aerial which picks up maximum signal when pointing "end-on" to a transmitter, and minimum signal when in the "broadside" position. When bearings on two or three stations have been taken, the point of intersection gives the position of the ship or plane.

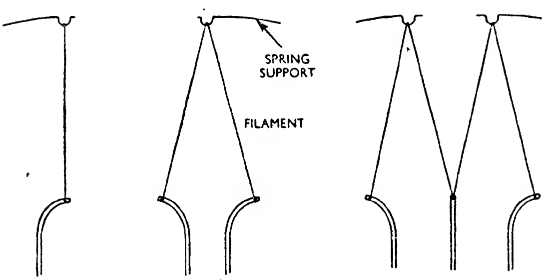
Often a *sensing* device, employing a second aerial, is incorporated to indicate the direction from which a signal comes, e.g. a bearing might reveal that a station is on a line due North/South and sensing would be necessary to determine whether the station was North of the receiver or South of it. Similar principles are involved in D.-F. stations located on the ground and which, when requested, determine the position of a ship or plane.

To give a ship or plane its position, three or more ground D.-F. stations work together. The ship or plane transmits a signal on which the stations take bearings. The figures are passed by two stations to the third which plots the intersection and transmits the position to the caller. All this is done in a minute or two.

Radio is used also for "homing" an aircraft. If there is a suitable transmitter at, or near, the airfield, a pilot can fly towards it guided by a frame aerial and this principle has been

elaborated so that a pilot can have either aural or visual indication that he is not deviating from his course. The frame aerial is used in conjunction with an open sensing aerial and arrangements are made whereby the receiver produces *dots* if the plane is off bearing to, say, port and *dashes* if to starboard. These two signals combine or "interlock" to give a continuous note when the aircraft is heading straight for the transmitter. See BLIND LANDING.

DIRECTLY HEATED VALVE. A radio valve whose cathode, in this case more usually known as a filament, is directly heated by the passage of an electric current through it. Such a cathode consists of a fine wire, either of tungsten alone, or of a wire coated with a special emitting material such as barium or strontium oxide (see EMISSION). Directly heated valves are generally used in battery-operated receivers and also in high-power transmitters. In the former case they have oxide-coated filaments and, in the latter, tungsten or thoriated tungsten.



Examples of directly heated cathode-filament structures used in valves for battery-operated receivers and small portable transmitters of the battery-operated type.

DISCHARGE LAMP. An electric discharge tube designed to act as a source of useful light.

DISCHARGE TUBE. A tube containing low-pressure gas through which an electrical discharge may take place between electrodes.

DISPOSABLE LOAD. A term used in reference to civil aircraft to denote the total weight available for passengers, mail, freight, fuel, oil and crew; i.e. disposable load equals maximum total weight minus tare weight.

DISRUPTIVE DISCHARGE. An electrical discharge due to the electrical breakdown of a dielectric (q.v.).

DISSOCIATION. The separation of a molecule into simpler fragments, such as atoms, ions, or simpler molecules.

DISTEMPER. A decorating medium used for ceilings and walls, which consists of a pigment, or base, mixed with water. Adhesion to the surface upon which it is placed, and cohesion of the particles forming the film, are obtained by the addition of a colloidal substance, usually diluted animal or fish glue.

In limewashing, a definite chemical change takes place both in the slaking, or wetting, of the solid, and again during the conversion of the wet film into a dry solid. In washable distempers and water-paints either or both forms of transformation may occur.

In limewashing, the material to be applied is made by slaking quicklime (freshly burned limestone) in clean water. The solution obtained has little body, and in the wet state does not obscure the surface upon which it is placed; upon exterior surfaces or in well ventilated situations, the water content is evaporated and the lime converted into calcium carbonate —a white, opaque solid firmly attached to any clean surface upon which it is formed.

Tinted or coloured washes of this type are obtained by first thoroughly wetting colour pigments which will withstand the action of lime. Lime blue, lime yellow, lime green, ochres, umbers and venetian reds, after thorough soaking, may be added to

the slaked lime and well stirred in. Again there is little evidence of colour or obscuring power while the material is wet, but both develop in a marked degree upon drying. Lime washing, the cheapest form of painting and decorating, is used extensively upon all types of surface.

In glue-bound distempers the fixing agent is animal or fish glue which, in its diluted form, is known as *size* (q.v.), and is prepared by soaking cake glue in cold water for 24 hours. Considerable increase in bulk takes place, more water is added and gentle heat applied; when solution is obtained, more water may be required. Experience or experiment will indicate the quantity needed to obtain a trembling jellied form when cold.

The base or main pigment is whiting (chalk). Clean water is placed in a bucket and the whiting added a little at a time until it stands in a cone shape above the water; allow to soak, then pour off the surplus water and mix thoroughly with the hand or a flat stick. If an off-white is required, the weak jellied size is now added and gently stirred in; for snow white, a little lime blue is first mixed with water and then added to the paste white before the size. All other pigments may be used, either alone or as tinting or colouring agents for the white base, providing they are not affected by free lime and are each thoroughly wetted with clean water before incorporation with the white or with size. A notable exception is made in the case of heavy pigments; these are worked into a paste form upon a hand board with weak jellied-size by means of a palette knife before being added to the base. This assures good distribution and prevents settling-out in the thinned material.

Glue-bound distempers are easily removed by wetting with water and sponging off. If new, the surface is rubbed with a medium-texture glass-paper and dusted down; it is then given a coating of weak, jellied size to neutralize any uneven absorption and, when this is dry, the distemper is applied with large brushes, evenly and progressively over the whole surface.

Normally only one coat of this type of distemper is required to obtain full colour value and obscuration of the surface. It is used upon canvas in scene-painting; to give the extra grip necessary the size content is increased and flexibility is obtained by the addition of treacle.

Washable distempers and water paints were developed to extend the serviceable life of paints diluted with water; the advent of the pigment lithopone (q.v.), which remains a dense white when ground in water, made possible the use of other mediums for this purpose.

By far the greater number of paints and distempers are bound by grinding the pigment in a liquid composed of oil and water emulsified with glue or wax saponified with water and an alkali and linseed oil. These are always supplied in paste form together with the appropriate (petrifying) liquid for their dilution. The range of colours available in this type is considerable as practically all the coloured pigments and dyestuffs may be used to supplement the inert white base.

With washable distempers the use of glue size should be avoided; if the plaster has been previously coated with glue size or glue-bound distemper, it must be removed by washing with hot water, otherwise with ageing the applied material will flake and leave the surfaces. The surface of both lime plaster and hard wall plaster is glass-papered, dusted off, and given one coat of the liquid supplied with the material. At least 48 hours must elapse before a thin coat of the distemper may be applied, and the same length of time before the final good full coat can be given.

If it has been previously coated with the same type of material the surface is laid-in with a weak solution of sugar soap and sponged-off with clean water.

DISTILLED WATER. Water which has been evaporated and then condensed; it is used for many purposes where pure water is required. One

use of distilled water is to maintain the level of the electrolyte in the cells of storage batteries. In certain districts, tap water is a suitable substitute but should be used only with expert advice.

DISTORTION. The failure of a valve amplifier faithfully to reproduce at its output the signal applied to its input.

Such distortion is of three main kinds: (a) *frequency* distortion, which occurs when different frequency components are not amplified equally, (b) *amplitude* or *non-linear* distortion, which arises owing to a non-linearity of the valve circuits and gives rise to the production of harmonics and (c) *phase* distortion, which is the result of the relative phases of the components of the signal being amplified, not being the same at the output as in the original signal.

DISTRIBUTION. The supplying of electrical energy to consuming points as opposed to bulk transmission from one place to another.

DISTRIBUTION BOARD. An arrangement of electrical apparatus at the place where a number of consuming points are collectively fed from a supply circuit.

Distribution boards generally consist of busbars, fuses, switches and similar apparatus.

DISTRIBUTOR (Auto. Engineering). A device for distributing the high-tension impulses, built-up in the secondary winding of the induction coil, to each cylinder of an internal-combustion engine in correct firing order. See BATTERY-AND-COIL IGNITION, FIRING ORDER and MAGNETO.

DISTRIBUTOR (Elec. Engineering). A line, or cable, from which tappings are taken to several consumers; a typical example is to be found in the street cable to which dwellinghouses are connected by means of service lines.

DIVERSITY FACTOR. The total electrical load which would be taken by a number of consumers, or consuming points, if they all required their maximum power at the same time, divided by the greatest total load actually experienced. Compare with DEMAND FACTOR (q.v.).

DIVERTER. A resistor, which may be variable, connected in parallel with a winding of an electrical machine. Its purpose is to divert a portion of the current which would otherwise flow in the winding, for example, the field winding of a series motor (q.v.).

DIVIDING HEAD. An attachment, sometimes known as an indexing head, used on milling machines; it is always supplied with universal millers and often with the plain type.

The dividing head consists of a device with ground conical centres between which the workpiece is held, whilst a handle enables the workpiece to be rotated through whatever fraction of a turn may be necessary.

Dividing heads are thus necessary for the machining of articles in which equally spaced grooves have to be milled; for example, reamers, cutters, ratchets etc., as well as milled gears. In plain indexing the workpiece is rotated simply by revolving the handle through the necessary angle and allowing a spring-controlled pin within it to engage with the corresponding hole on the dividing plate. Compound indexing involves the turning of both the handle and the index plate, the rotary movements of these two parts being co-ordinated so as to give the requisite angle of rotation; it is carried out by withdrawing a stop-pin from the back of the index plate, which is then free to turn.

An *optical* dividing head has been devised to ensure more accurate settings than are possible with the normal type; it embodies a glass dial carried on the spindle and having its periphery divided into 360 deg. A microscope is used when indexing to observe the number of divisions through which the dial is turned. As the eyepiece of the microscope gives a magnification of 60 diameters, the graduations are enlarged 60 times, and therefore the angles through which the dial rotates can be read in minutes. By means of a vernier scale projected on to the field of observation, settings

within 20 sec. ($\frac{1}{180}$ deg.) can be estimated.

DIVALENT, see VALENCY.

DIVINYL, see BUTADIENE.

D-LAYER. The name given to one of the electrified layers in the ionosphere (q.v.). See RADIO-WAVE PROPAGATION.

DOOR FRAME. A framed piece of material placed along the sides and top of a door opening; the part to which the door is hung. The frame may be plain or rebated, the rebates being intended to accommodate the door and to form a stop. Frames may be fixed in plain, or straight-through, or recessed jambs. They are secured in position by a system of wedging, and nailing to wood plugs driven into the joints of the surrounding brickwork, or by means of dowels in the feet of the posts and wrought-iron anchors on the sides. But in some instances the frames are built-in as the surrounding brickwork is placed into position. Recesses in brick jambs are usually $2\frac{1}{4}$ in. deep.

DOORS. The types of door used in buildings may be grouped under three headings: ledge-and-batten, panel and flush doors, shown in Fig. 1. There are many variations, especially of panel doors, which are named according to the number of panels or according to the style, as Gothic, sash etc., or to some special use or feature. Special types are: composite, double, dwarf, folding, fire-resisting, french, jib, revolving, sliding, stable, swing, trap and warehouse doors. The standard sizes for ordinary doors are 6 ft. 4 in. × 2 ft. 4 in.; 6 ft. 6 in. × 2 ft. 6 in.; and 6 ft. 8 in. × 2 ft. 8 in.

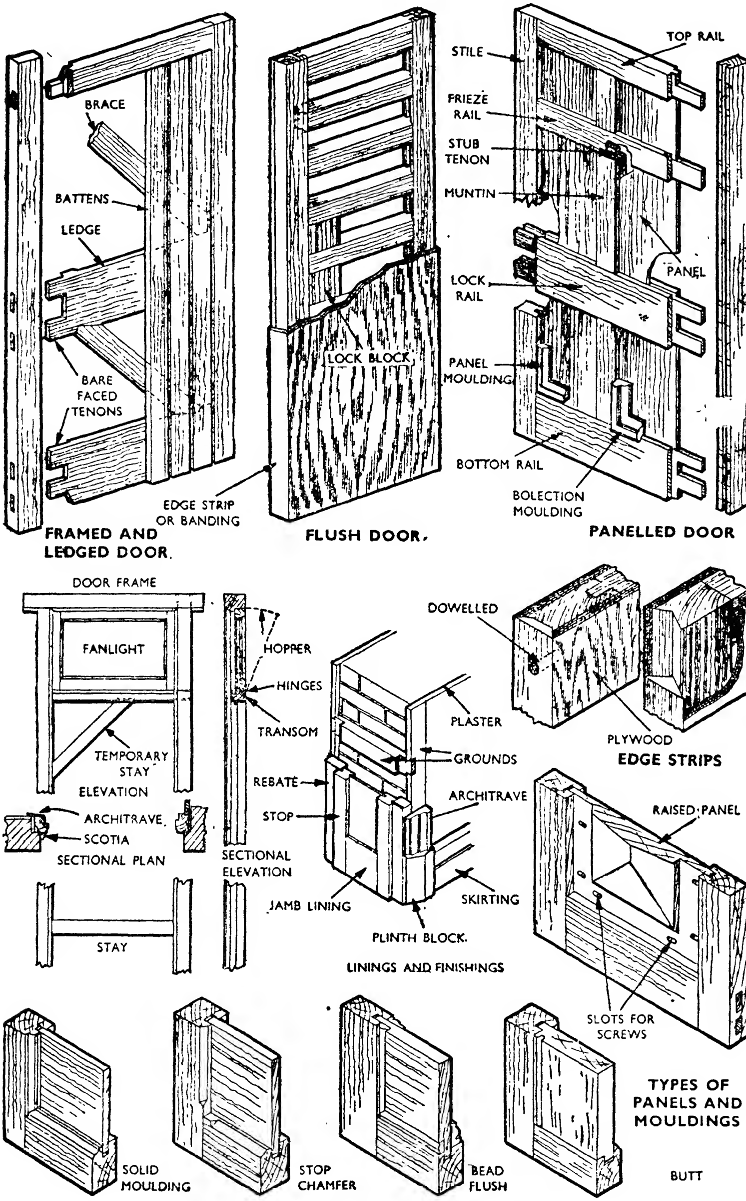
LEDGED DOORS. The simplest form of this type of door, which is also called a *batten* door, consists of $\frac{7}{8}$-in. boards, or battens, and ledges, about 5 in. × $1\frac{1}{4}$ in. They are used for outhouses, yards etc., and are hung with tee hinges or bands and gudgeons, and secured by a Suffolk latch and bolt or stock lock.

Braces are often added to prevent the nose from dropping. The best type, as shown in Fig. 1 overleaf, is a framed, ledged and batten door. The bottom ledge is sometimes replaced by a rail equal in thickness to the stiles, and rebated, as is the head, for the boards. They may have three narrow ledges instead of the two wide ledges, and the braces may be omitted. Many period doors, such as Gothic, Tudor etc., are framed in this way and are hung with decorative bands and gudgeons.

PANEL DOORS. There are numerous varieties of panel doors, but the principles illustrated in the six-panelled door are generally applicable. The number of panels varies from one to six in modern design, but there may be twelve or more. The usual type has four panels, but in large superior doors, five or six are used. Several varieties of panel are shown. In good-class work raised panels are common, and if they have plane faces are called fielded panels. The mouldings round the panels may be planted or stuck on the solid. It is usual to have bolection mouldings (mouldings which stand above the framing) on one side and panel mouldings on the back. Plain panels are usually of plywood, and slot screwing is unnecessary.

GUNSTOCK DOORS. When the upper part of the door is glazed, it is usual to diminish the stiles above the lock rail. In this case a gunstock, or diminished stile, joint is used. (See JOINTS.)

FLUSH DOORS. In recent years the flush door has superseded the panel door. The development has been rapid, owing to improvements in glue and synthetic resins. The types are very varied according to the manufacturer, but they are all mass produced and outside the scope of the ordinary woodworker, as expensive equipment is required. The usual type, shown in Fig. 2, consists of a frame faced with plywood, and the variation is in the frame and edgings. Sound-resisting doors have a fibre core. Superior doors may be veneered. Laminated wood may be used, but in this case the result is a *solid* door. In all cases the doors have flush, unbroken faces, except for a small, glazed panel at the top for hospital



CONSTRUCTION OF DOORS

Fig. 1. Effective operation of a door depends primarily upon good workmanship in construction and hanging. Above are shown various types of door and their respective constructions, together with the appropriate mouldings, frames and fixings.

and exterior doors. One edge, or both, has a strip to cover the edge of the plywood. When fitted only on the shutting stile it is often called a slamming strip. Panel and flush doors are hung with butt hinges and usually secured by a mortise lock.

SWING DOORS. These are usually panel or flush doors, opening both ways. The only difference is in the hanging. A floor spring at the bottom and a pivot at the top is the usual method, but helical hinges may be used.

FRAMES AND FINISHINGS. Interior door frames are called linings or casings. They usually consist of boards, rebated on one edge. For thick walls and superior work, panelled linings are often used, as shown. These are secured to grounds fixed to the brickwork. The rebates may be cut out of the linings, or planted to allow for shrinkage. An *architrave* is mitred round the opening, and in addition, *ancones* and *pediment*, or some other form of door head, may be used as a decorative feature. An external door frame with fanlight is also shown. The stiles and head are usually of 3 in. × 5 in. stuff.

MISCELLANEOUS DOORS. *Double* doors consist of a pair of doors meeting with a rebate at the middle stiles, unless they are swing doors, when the meeting edges are rounded. *Folding* doors have two or more leaves hinged to each other, for opening in a confined space. A *double margin* door has the appearance of double doors, but it is framed together as one door with the inner stiles keyed together with folding wedges. *French* doors are simply large glazed sashes opening as doors. *Dwarf* doors are less than 5 ft. high.

Jib doors are designed to present an unbroken appearance in a wall, and are often disguised as part of the wall. *Revolving* doors are used at the entrances of public buildings. They may have two or four wings revolving round a central axis. They are intended to afford easy entrance and to prevent draughts. *Sliding* doors usually slide horizontally on runners

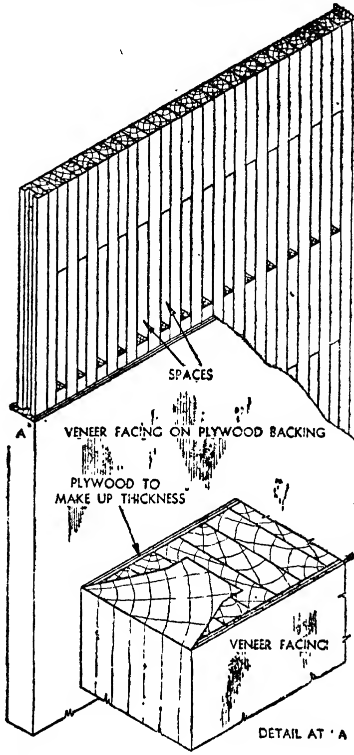


Fig. 2. Flush door consists of a strong frame faced with plywood; it may also be specially fitted with a fibre core to make it more sound-proof.

against a wall. The runners may be on the ground or overhead. *Stable* doors consist of two short ledged-and-batten doors one above the other so that the top part only may be opened when required. A *warehouse* door is a large frame-and-batten door. If it is in one piece it is usually a sliding door, but it may be in the form of double doors hung with bands and gudgeons. A *wicket* door is a small door for pedestrians framed in a large gate or warehouse door.

DORMER, see DORMER WINDOW and ROOF LIGHT.

DORMER WINDOW. A vertical window projecting from the surface of a pitched roof. Dormers can be constructed in a timber-frame roof

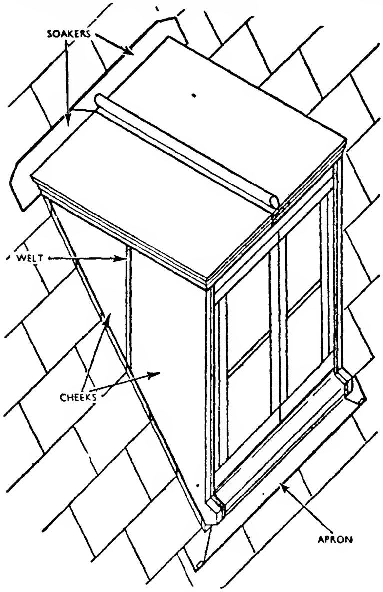


Fig. 1 (above). Leadwork on a dormer window built on a timber-frame roof.

asphalt in preference to sheet lead.

A dormer built on to a timber-frame roof is shown in Fig. 1. The apron is fixed before the window frame is placed in position, the lead being taken up behind the sill to form a water-tight joint. Soakers (q.v.) form the top joint between the roof and the dormer, and where the cheeks are in two pieces they are joined by means of a welt. A bossed-lead soaker is used for weathering each corner of the dormer at the joint of the roof and the sill, this often requires careful bossing and working. These various processes are illustrated in Fig. 2.

DOUBLE-ACTION PRESS. A press so designed that each punch or blank holder has an independent movement. The machine comprises two slides, an inner and an outer, operated by different eccentric throws or cranks, so that one moves in advance of the other. Thus the outer slide carries a punch and a blank holder so timed as to stop during a quarter revolution of the crankshaft

or a concrete-and-hollow-block roof. In the former the rafters are trimmed, the trimming rafters being thicker than the common rafters. The projecting framing is made up of corner posts, head pieces, sill and studs. The sides of a dormer, called cheeks, are usually close-boarded and covered with sheet lead. The roof of the dormer may be pitched or flat, i.e., slightly inclined towards the front or towards the main roof, when it is similar in construction to a flat timber roof. When a dormer window forms part of a concrete roof, the roof of the dormer is usually covered with two layers of mastic

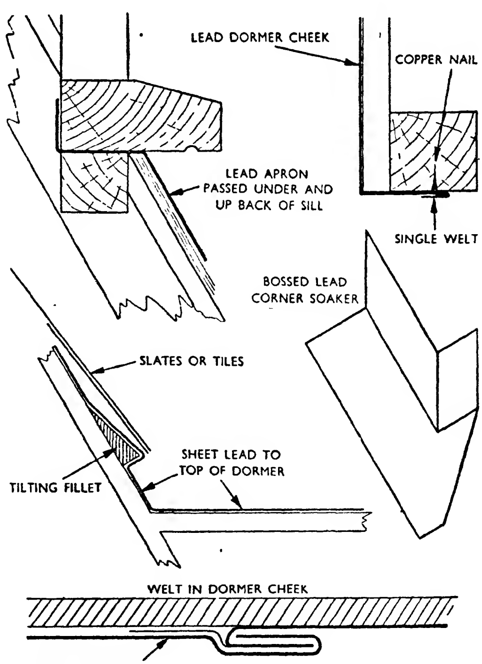
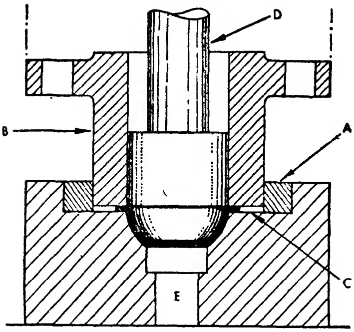


Fig. 2 (right). Details of apron, soakers, cheeks and sill of dormer window.



Sectional view of a simple double-action press, showing: *A*, blanking or shearing die; *B*, blanking punch and blankholder; *C*, drawing die; *D*, drawing punch and *E*, ejector.

after the blank has been sheared. In this position the blank is held between the end of the punch and a recess in the die. The main features are shown in the accompanying diagram.

The holding pressure can be regulated, and during this dwell of the outer slide, the inner slide with a drawing punch moves downward to draw the metal into the die to form a cylindrical or cup-shaped work-piece. The timing of the drawing punch is such that it does not reach the blank until the latter is fairly held by the blankholder of the outer slide. The main advantage of the double action is that it simplifies die design. Small machines can have the blank-holder cam-operated, while on heavy presses it is operated by toggle levers.

DOUBLE-CUT FILE, see FILE.

DOUBLE FLOOR. For spans of more than 16 ft., beams should be introduced dividing the area into two or more bays. When timber beams are used, they are called *binders*. It is now common practice to use rolled steel beams (R.S.B.) instead of timber. The timber joists may then be framed to obtain support, or they may rest on the top flange of the steelwork.

DOUBLE-HUNG SASHES, see CASED WINDOW FRAMES.

DOUBLE TUP, see EARING.

DOUBLE-TONE INK. An ink used to produce half-tone prints with photographic or gravure similarities, made both for lithographic and letterpress printing. The inks are used in the normal way, the overtone appearing some hours after the printing has been done. The reason for the peculiar effect is that the ink is a combination of oil-soluble dye with a stable pigment and vehicle. After printing, the dye spreads and stains the paper as a halo round the dot or printed image. The chosen dye differs in hue from the body pigment, and beautiful effects can be obtained with a single printing, particularly when toned papers are used. Slight difficulties are experienced when double-tone inks are used for lithographic printing.

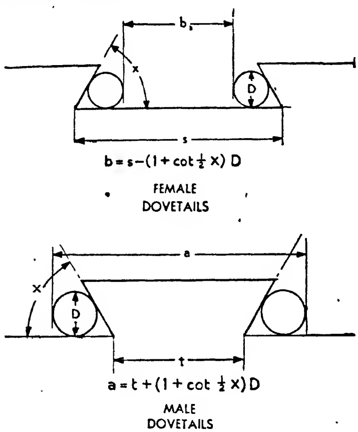
DOUBLY FED SERIES. A type of single-phase electrical commutator, or repulsion, motor in which the armature is fed partly by conduction and partly by induction. See MOTOR.

DOUGLAS FIR. A resinous, strong, fairly durable and easily wrought wood, something like redwood, found in N.W. America. It is an established favourite for good-class constructional work, joinery, plywood etc. Owing to the grading, it is more dependable than redwood, and may be had in much larger sizes, baulks 4 ft. square and 70 ft. long being obtainable. See TIMBER.

DOVETAIL JOINTS, see JOINTS.

DOVETAIL SLIDE. An arrangement of sliding surfaces, with their sides set at an angle to one another so as to interlock with a grooved base or mating surface, used in machine-tool practice where it is necessary for a sliding component to move along the ways of a machine-bed without rocking or lifting, as, for example, in the slide rest of a lathe.

To take up the play, or clearance, between the grooved portion and the slide, a gib is generally introduced. The angles between the two planes in the dovetailed item are usually made from 45 deg. to 60 deg., the latter being simpler to make accurately. The actual angle chosen depends upon the amount of space at the designer's



Dovetail slides may be checked for accuracy by inserting rods as shown.

disposal; a 45-deg. angle will need more room than a 60-deg. angle, but will have less tendency to wedge.

For a given set of conditions, however, a 60-deg. slide will be stronger than a 45-deg. slide. Dovetail slides can be checked for parallelism by inserting circular rods in the angles, as shown in the illustration, and measuring the distance *a* (for male dovetails) and *b* (for female dovetails).

DOWEL PINS, see NAILS.

DOWNPIPE. A rain-water pipe; one that carries away rain water only, as distinct from a soil or waste-pipe.

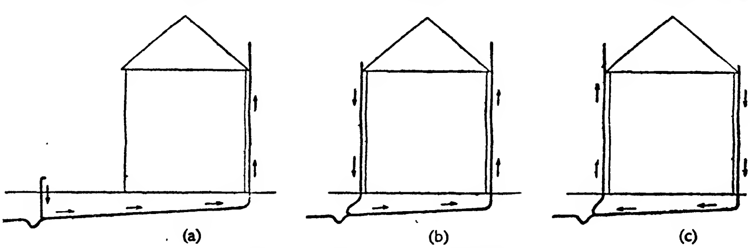
DRAG (Aero. Engineering). The resistance experienced by an aircraft when it moves through air. Drag may arise from several causes, i.e. induced drag, skin friction drag and form drag. Induced drag and skin friction are defined elsewhere; *form* drag is the term applied to the resistance due to the air pressures acting on the aircraft. *Profile* drag is the sum of skin friction and form drags.

DRAG (Foundry). The bottom half of a mould or moulding box. See MOULDING BOXES.

DRAG LINK. The bar or link connecting the steering arm on the stub axle of a mechanically propelled road vehicle to the drop arm (q.v.) of the steering box. It transfers the pushing and pulling effort from one to the other, and is sometimes known as the push-and-pull rod. See STEERING.

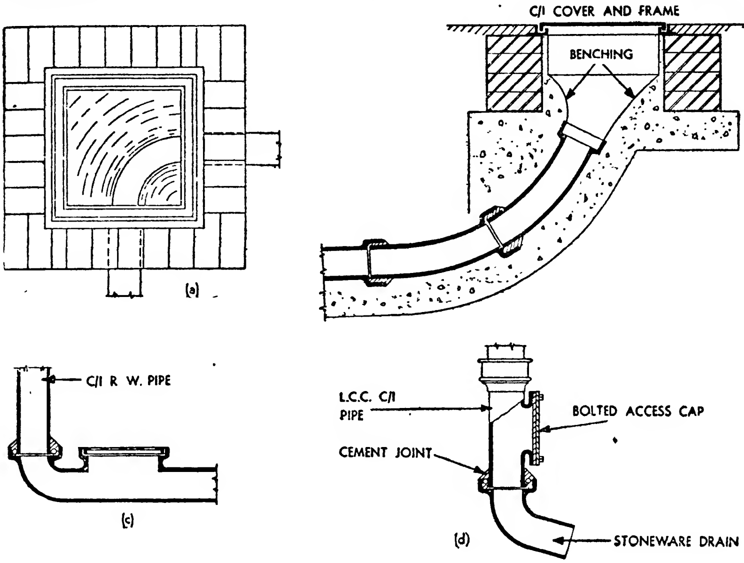
DRAGON'S BLOOD. A red-brown resin used in finely powdered form in the photo-engraving printing process for preserving the image sections of the metal from attack during the etching operation. It changes colour when melted, thus assisting control, but a greater advantage is that it does not spread when melted, and formation is retained on re-solidifying. It melts at the comparatively high temperature of 120 deg. C.

DRAINAGE. That part of a system of sanitation above or below ground through which waste water or sewage is conveyed to the sewer or to other means of disposal. The provision of a drainage system to a building is legally enforced under by-laws made by local authorities under the Public Health Act, and it is necessary to conform to such laws when planning



VENTILATION OF DRAINS

Fig. 1. Inlet and outlet pipes are necessary to provide adequate ventilation of drainage systems. Above are shown three installations widely used today.



MEANS OF ACCESS TO DRAINS

Fig. 2. Various devices in general use to facilitate inspection and cleaning of drainage systems. These are best installed at changes of level and direction and at the principal branches; below ground level they must have brick manholes.

new systems of drainage, or alterations to existing ones.

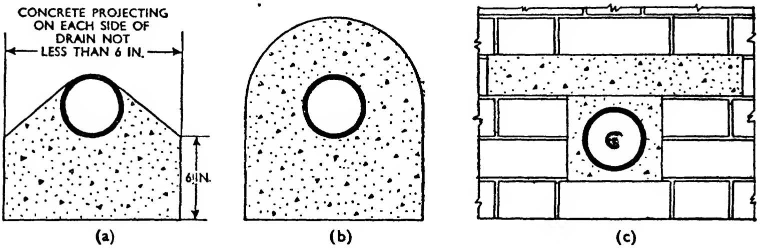
Adequate ventilation of drains is essential. Except when water flowing through the pipes causes sufficient movement of the air, ventilation will depend solely upon air currents and convection. To provide sufficient fresh air in a drainage system, inlet and outlet pipes are necessary, though on account of wind currents and differences of temperature between the air in the system and that outside, the inlet and outlet must be capable of working in the reverse order if necessary.

Systems incorporating a "low-down" inlet, Fig. 1(a), have sometimes been installed but these have the disadvantage that foul air may escape at the worst level possible. It is therefore more satisfactory to use ventilating pipes which are carried up to a height sufficient to ensure that no foul air emanating from the system shall be injurious to health. This system is shown in Fig. 1(b) from which it will be seen that the outlet pipe at the rear of the building reaches a higher level than the inlet at the front. When, as in Fig. 1(c), the outlet is placed at the front it must still be carried well above the level of the inlet.

There are two main methods of drainage, known as the *combined* and the *separate* systems. In the combined system, both sewage and surface water are carried to the sewer in one set of pipes; in the separate system, however, the sewage and surface water are kept apart.

The general principles of good drainage are the same in both the separate and combined systems. The drainpipes should be of a size adequate to take the estimated flow, and to be self-cleansing should be laid to proper falls. The foundations should be such that there will be no breakage by subsidence.

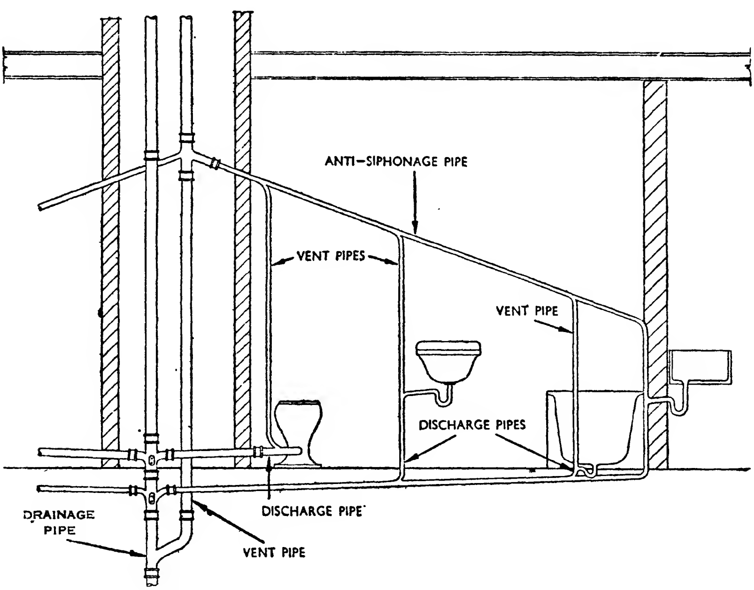
Further, the drains should be arranged in straight lines between



PROTECTION OF DRAINS

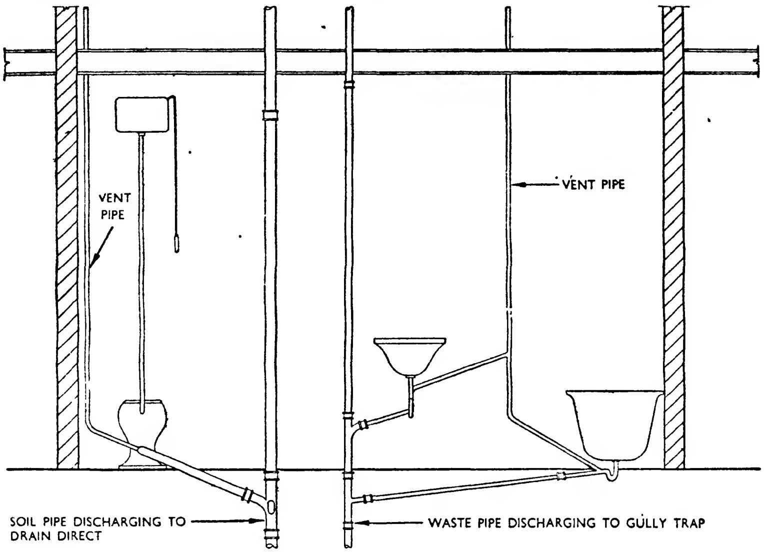
Fig. 3. Method of laying drains in concrete: bedding and flaunching for stoneware and cast-iron drains; (a), concrete bedding and covering for stoneware drains (b) passing under a building; and drain passing through a wall (c), protected by a concrete or stone lintel, brick arch or rolled-steel joist to give extra strength.

fixed points, such as inspection chambers, so that clearing and testing are simplified, and an interceptor should be placed at the point of discharge into the public sewer. Each part of the system should be properly ventilated and, wherever possible, drains should be outside the building, while the construction should be such that the whole layout is air- and water-tight. Branch drains should be kept as short as possible, and very deep drains should be avoided. The depth will be governed by the depth of the interceptor, which should be as near to the boundary of the premises as possible, depth and position usually being arranged with the local authority into whose sewer the system is to be discharged. Deep interceptors are necessary when any basement drainage has to be dealt



ONE-PIPE SYSTEM OF SOIL AND WASTE PIPES

Fig. 4. All sanitary appliances in one-pipe systems discharge into a common pipe.



DUAL SYSTEM OF SOIL AND WASTE PIPES

Fig. 5. In this system, waste and soil fitments discharge into separate pipes.

with, but additional new drains, if convenient, may be laid at a higher level with a drop into the deep chamber.

In order that every part of a drainage system shall be readily accessible, means of access must be provided in the form of inspection chambers at convenient points, preferably at changes of direction, changes of level and at principal branches. Rodding eyes (Fig. 2b) are useful at changes of direction and also at the top end of a long branch drain.

Where a rodding eye is provided, the drain must be brought up to ground level so as to permit easy manipulation of drain rods. Inspection bends below ground level are not to be recommended but, where used, brick manholes should be built round them, brought up to the ground level and fitted with a sealing cast-iron cover (Fig. 2a). Entry to branch drains may also be provided by means of an access cover at the foot of each rain-water pipe (Fig. 2c) and soil pipe (Fig. 2d), or by the use of access gullies.

Where drains pass into or under buildings, the pipes must be adequately protected by concrete, as shown in Fig. 3.

The one-pipe system (Fig. 4) permits the discharge of sanitary appliances into one main soil or discharge pipe without, in the case of waste-water fitments, the interposition of a gulley trap.

This system proves most suitable where all fitments can be grouped closely round the main pipe, as in blocks of flats, offices, hotels and factories.

In large buildings, however, it is usual to instal the whole of the pipework internally, and to fix the vertical stacks in pipe ducts or plumbing spaces. The main discharge pipe must be carried up as a vent above the highest branch pipe and terminated in the same manner as a soil pipe (q.v.).

Branch waste and ventilating pipes form a circuit from the main discharge to the main ventilating pipe, so that the lower part of the circuit acts as the waste and the top part as the vent pipe. The one-pipe system requires two main vertical stacks—discharge and

vent—while the branch pipes are similar to those of the dual system (Fig. 5), the main consideration being that the pipes should be large enough to take the double flow.

DRAIN COCK. A tap screwed into the bottom of a tank or container to enable fluid to be drawn off as required.

DRAINPIPE. Cylindrical sections of glazed stoneware or cast-iron, with socketted ends for easy jointing, as shown in the accompanying illustration; they are used to carry away surface water or sewage. Concrete pipes are sometimes used, but mainly for sewers of 12 in. and over in diameter. Stoneware pipes possess a smooth, even bore, but require more joints than cast-iron pipes, and are liable to easy fracture from vibration or ground subsidence. Cast-iron pipes have greater strength and need fewer joints. In order to prevent corrosion they should be protected by Bower-Barffing or by coating with a bitumastic solution.

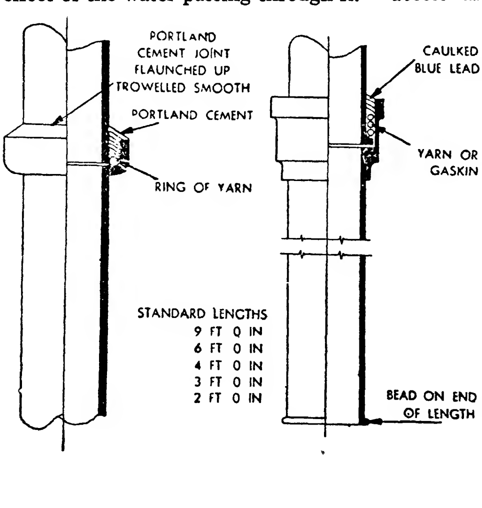
No drain may be less than 4 in. in diameter, and a 4-in. drain flowing full will discharge approximately 140 gallons per minute, usually quite sufficient for the peak period of flow from an ordinary dwelling house. It is a disadvantage to have drains too large, as the smaller pipe will be more self-cleansing, owing to the scouring effect of the water passing through it. Rapidity of flow, however, also depends on the fall (q.v.).

DRAIN TESTING. The process of testing a drainage system for leaks. Four main methods can be employed: water, smoke, air and chemical tests. In the water test the drain is plugged at the lower end and water allowed to run in until the drain is filled. The test should remain on long enough to indicate soundness or otherwise, and the defective drain will be noted by a drop in inches or loss in gallons per given length of time. A reading can usually be taken by fixing a gauge to a manhole or gulley top as required.

In normal circumstances a branch drain to a gulley can be filled only to the top of the gulley. If a greater head of water is needed, therefore, the gulley will have to be plugged with a bag, and a tube and funnel inserted in the plug in the manhole, the length of the tube corresponding to the head required.

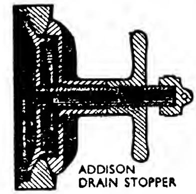
In new drains allowance should be made at the beginning of the test for porosity, especially when yarn has been used in the caulking of the joints.

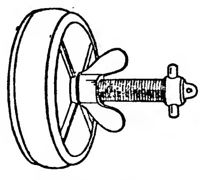
The smoke test consists of pumping smoke generated in a smoke machine into the drain and noting any escape through the ground or joints, should they be exposed. This method is useful in testing old systems of drainage where normal means of access are difficult or non-existent. The smoke test can be applied under pressure by plugging the drain, in which case the dome on the smoke machine will rise as the pressure rises, remaining constant, providing there are no leaks, when pumping ceases. Smoke rockets should be used with discretion, as the volume of smoke

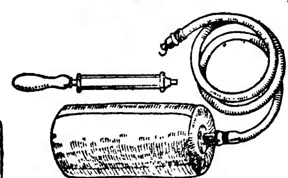


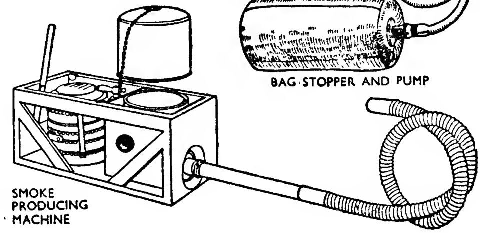
Two methods of making water-tight joints in drainpipes. On the left is the appropriate joint for stoneware pipes, and on the right that employed on heavy cast-iron piping.

Various appliances used, as explained in the text, in the process of testing drainage systems for leaks.









they produce is small, and is applied at only atmospheric pressure.

The pneumatic test is usually applied to soil and vent pipes. When a pipe is found by this means to be defective, however, the smoke test has to be used to discover the position of the defect. In any case, the pressure must not be too high, or air will be forced through the water seals of the traps.

If high pressure be insisted upon, the test must be made before the W.C. pans are fitted, so that a plug can be fixed in each junction. For low pressure a simple gauge can be used consisting of a U-tube partially filled with water, the gauge being fitted to the pumping tube without releasing the air. Air pressure in the drain or soil pipe then causes the water to rise in one leg of the tube, where, providing there is no defect, it will remain constant.

The chemical test gives somewhat uncertain results. Strong-smelling chemicals are discharged into the soil pipe, through the trap of a gulley or W.C., usually in a container on the end of a piece of string so that the container can be withdrawn, and defects or leakages noted by the pungent smell. The uncertainty of the test lies in the fact that the odour may be blown back into the premises after it has passed out of the soil pipe.

DRAWABILITY. Common metallurgical term indicating the willingness of a metal to be pressed, drawn or similarly formed without permanent damage to the structure; this general statement, however, presupposes efficient tool design and skilled handling. No precise method of evaluating drawability has yet been devised.

The desire for knowledge of this feature in metals may be divided into two parts, (a) fundamental, as in the case of the research worker, and (b) practical and general, as is required every day in industry. In the former all the usual laboratory tests can contribute data, and the whole may be aggregated into a fairly precise assessment.

The various tests of ductility, cupping tests such as the Erichsen test, microscopic examination and full-scale examinations on the actual press, all assist in determining how the metal will ultimately behave in practice, but there is no generally accepted complete test. Extensive research is being continually made on the whole problem, and Prof. H. W. Swift has suggested a practical testing procedure of deep-drawing properties involving two separate tests. He has made it clear that a properly devised "drawing" test measures different properties from those revealed by a "cupping" test, and that the two tests cannot be interchanged. He suggests that a suitable specification should stipulate a minimum Erichsen value and a minimum successful drawing ratio, these minima being determined according to the

drawing conditions to which the material is to be subjected.

DRAWBACK. In foundry work, part of a mould made separately and fitted to the main mould like a core,

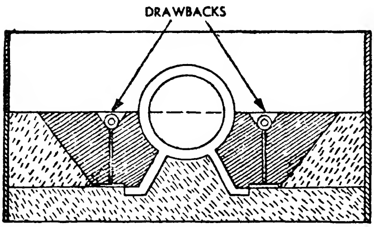


Diagram showing use of drawbacks in moulding barrel with projecting feet.

as shown, with the object of minimizing the number of joints in a mould. As the name implies, this may be "drawn back" from the mould so that a pattern or core may be removed.

DRAW-OFF (Plumbing). Any pipe or tap for drawing water, particularly the tap on the premises side of the main stop cock, used for draining the layout in the event of frost or repairs. In dwelling houses this tap usually serves as a drinking-water supply over the kitchen sink. Where, however, there is a long run of pipe between the point of entry into the building and the sink, a further draw-off should be provided near the stop valve.

DRIERS (Painting). Materials which when added to a paint containing oil, expedite the drying process. For paints, driers are used in two forms—paste and liquid.

Paste drier consists of the drying agents—the salts of various metals, lead, manganese etc.—and non-drying mineral matter and linseed oil ground into a smooth paste. A standard drier of this type when added, at the rate of 5 per cent by weight, to the other ingredients of the paint, should not cause the film to become surface-dry in under eight hours but it must be dry and in a satisfactory condition to receive the next coat within 24 hours.

Liquid driers are made by incorporating the drying agents with linseed oil by heating and, when cooled, by the addition of considerable quantities of turpentine or white spirit. Normally these are rather dark-coloured thin liquids, so diluted that a standard one, added to the other ingredients of the paint at the rate of 5 per cent of the total weight, obtains results similar to paste driers. With a liquid drier, paint seldom requires any additional diluent. Care is necessary in the use of driers of both types, a superabundance being liable to bring about an alteration in the atomic structure of the film and so cause its premature breakdown.

DRIERS (Printing). Chemical compounds of metallic salts, usually of cobalt, manganese or lead, added to printing inks to assist their drying or other properties. Driers are dispersed separately or in combination in a suitable vehicle, or liquid medium, such as vegetable oil or volatile thinner, together with a resin, and are added in small quantity to printing inks either to shorten the drying time or to produce specific ink-film conditions.

Cobalt is the strongest drier, but produces a glazed surface skin. Manganese is less strong and produces a similar effect more slowly. Lead is the weakest, but it produces a uniformly dry film and a dull surface which will accept overprinted ink films. A combination of manganese and lead results in a drying activity which is out of proportion to the amount of lead or manganese added. Addition of an excess of driers to printing ink often retards the drying time, and always impairs the working properties of the ink.

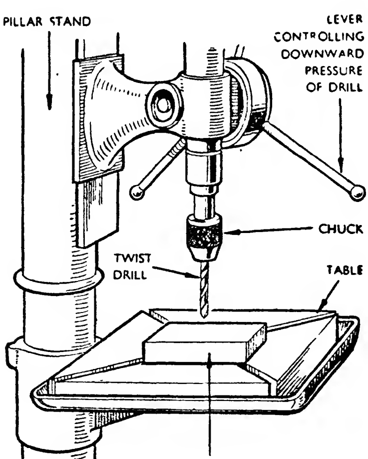
DRILLS AND DRILLING MACHINES. The most widely used type of drill for metal is the twist drill, having two flutes or grooves. For enlarging and finishing the internal surfaces of punched holes, drills with three or four flutes are generally employed. Because they have flat ends, they cannot be made to drill solid metal. Some twist drills are made with a small oil-hole through the longitudinal axis to facilitate the

drilling of deep holes, which is sometimes a rather difficult operation. Oil or cutting fluid is forced under pressure into the hole and lubricates the cutting edge, whilst the chips of metal removed are ejected in the usual way through the flutes.

Drills of this type are always made with shanks, which are cylindrical or have a standard taper; the Morse taper is adopted, the standard range embodying eight different sizes, numbered from 0 to 7 inclusive.

The sizes of twist drills are generally designated by the actual diameter, except for small work, where numbers may be used. Some firms use a range of letters of the alphabet to denote medium-sized drills from 0·234 in. to 0·413 in. in diameter, the increase in diameter in advancing from one letter to the next varying from 0·004 to 0·014 in. Twist drills are usually made of plain carbon tool steel, but finishing steels, high-speed steels and super high-speed steels are also used.

DRILLING MACHINES are of various types, the chief varieties being the ordinary upright machine, the radial drilling machine, the multiple-spindle



Upright drilling machine with adjustable table enabling workpiece to be held in the appropriate position.

type, the sensitive drill, for delicate work only, and the portable drill operated by compressed air. The upright machine illustrated has a spindle rotating about a fixed vertical centre line, but the table can be swung through an arc and clamped at the best position.

In the radial machine the reverse principle is adopted, the table being fixed and the spindle free to move sideways along a massive arm which can be swung through a large angle, so that any point over, or near, the table can be covered. Some drills for use on mass-produced articles are provided with turrets carrying tools with which a succession of operations —drilling, expanding or counter-boring—can be carried out in their correct sequence.

DRIP. A ridge formed on the surfaces of large flat roofs to facilitate the jointing of sheet-lead covering. Drips should not be more than 3in. in depth and not more than 9 ft. apart, and should be formed with a horizontal groove in the vertical edge of the timber so that the lead undercloak can be dressed into the groove, thereby preventing capillary action.

DRIPSTONE. A label or hood placed over the heads of door and window openings to throw the rain water clear of the aperture. In masonry, a dripstone is formed by cutting a groove in the under surface of a projecting moulded course of stone. The purpose of the dripstone is to shed the rain water clear of the wall surface.

DROP ARM. On road vehicles, the spindle projecting from the steering box at the base of the steering column. When the steering wheel is rotated the drop arm transmits the pull-and-push effort to the drag link (q.v.). See also STEERING.

DROP FORGING. A method of die forging used mainly in the motor engineering trade, where large quantities of the article or shape required offset the original high cost of the dies. The material used, ferrous or non-ferrous, is first heated and then placed between the two dies or moulds;

hammer blows complete the forging of the material to shape. The hammers used are generally driven by compressed air or steam.

DROP STAMP. A machine for shaping sheet metal, closely akin in design and operation to the press. The main features of a modern drop stamp are shown in Fig. 1, from which it will be apparent that to a certain extent the principles of "drawing" are followed. The main differences between this machine and a press are that the drop stamp is simpler in design, uses soft-metal tools, and is capable of completing a severe draw by means of several operations without the tools being changed.

Both tools on the drop stamp may be made of zinc, or one may be zinc and the other lead, or rubber may be used for the upper tool. The lower tool is usually cast first (zinc) and the sequence of operations is as follows: To begin the moulding process either (1) a sand mould may be made in the conventional manner from a wood pattern, or (2) a plaster of Paris pattern may be made from a hand-fabricated part or from templates and the mould made therefrom.

The zinc is melted in a suitable furnace, and the required alloy additions may be made; the pouring temperature is 454 deg. C. The upper tool is cast into the lower, and if the alloy is again used the pouring temperature is lowered to 420 deg. C. to avoid distortion. Setting shrinkage of the male tool is sufficient to allow the formed metal to lie between the tool faces. It is not considered good practice to use all new or all secondary metal in the melt for either tool.

The top tool is first fastened in the stamp either by means of bolts in the tool itself and nuts in the hammer head, or by nuts cast in the tool to correspond with bolts in the head. There are several objections to the latter practice, especially when the threads become worn; they are inaccessible for renewing and cannot be inspected, therefore failure is liable to occur without warning. The best practice is to cast the bolts in the tool, an added advantage of this method being that a means of manhandling the tool is thereby provided.

Since zinc and lead are relatively softer than steel, the finishing pro-

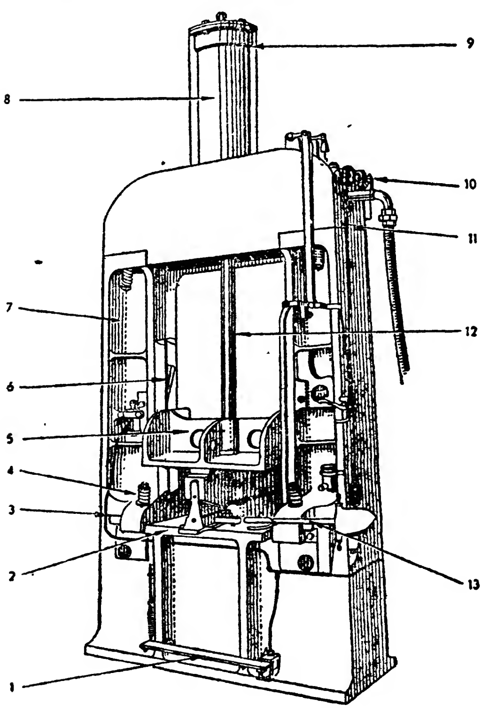
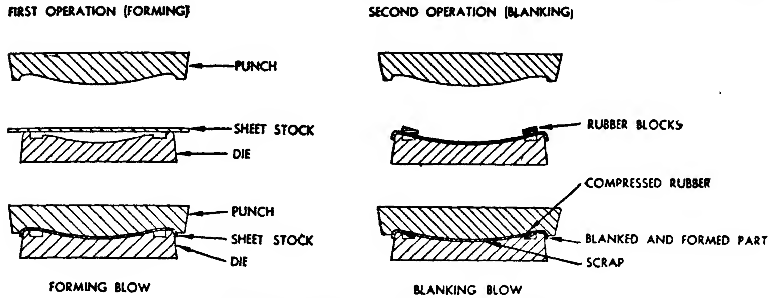


Fig. 1. Features of a drop stamp: (1) air-operated safety pedal; (2) solid one-piece anvil; (3) anvil frame; (4) alloy-steel bolts under tension; (5) ram; (6) safety latch; (7) I-beam frame; (8) self-draining cylinder; (9) safety cylinder head; (10) quick-acting valve; (11) top yoke; (12) forged-steel rod and (13) pivoted control lever.



OPERATIONS IN DROP STAMPING

Fig. 2. Drop-stamping machines are very much like presses, but they are simpler in design. The sheet stock is laid on the die and the punch brought down on to it; this is the forming blow. Before the blanking operation, rubber blocks are inserted, as illustrated above, and the final operation then takes place.

cesses for drop-hammer tools are simple; the standard practice is to machine level on the bottom, and then polish on the inside of the tool. With careful setting and adequate cleaning by means of buffing and polishing, the two tools should set with an overall accuracy of $\pm 0{\cdot}004$ or $0{\cdot}005$ in. The softer metal is always used for the male tool.

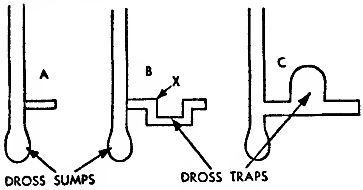
The lower tool is set first. All bolts on the anvil are slacked off, and the tool placed approximately in position. A number of strips of metal of the required gauge to be formed are placed at suitable positions in and around the bottom tool. The top tool is then placed in position inside the bottom, and both are placed on the hammer anvil in alignment with the tup, or upper member. This setting is found by dropping a plumb-line through the holes in the tup until it meets the centre of the bolts. The tup is then lowered gently into position and bolted, and both tools are now correctly centralized. The bottom tool can be made secure by clamps held on lugs which are part of the casting, or inserted into cored holes in the casting, or by bolts screwed in the anvil and a layer of lead run all round the casting, or by both methods.

While many pressings may be formed on drop stamps by means of a single blow, this method is not always suitable. It is then usual, particularly with harder metals or complicated stampings, to use the draw method, the blank being laid in position on the die and covered with a metal drawring of 10 S.W.G. Duralumin, which does not require machining. A number of plywood rings ¼ in. thick are now superimposed, the number depending upon the desired depth of operation. The various operations are shown in Fig. 2.

After each draw, a blow is made to rid the metal of any trace of wrinkle, and a ring is removed, and so on, until the operation is completed; layers of rubber may be interposed at the final operation. A final blow sets the metal. A vital point for complicated pressings is that the blank may be reduced in development size before the various operations. The points at which this reduction is necessary are found in the manufacture of the first off, and these contours will then suffice for an indefinite number of pressings.

DROSS TRAP. A device used to prevent oxides or dross, formed in melting certain metals, from entering the mould. Some form of trap is essential when casting aluminium-bronze, not only to ensure a sound casting, but, since the dross formed—largely aluminium oxide—is a powerful abrasive, to prevent undue wear of the tools used in machining the casting.

A simple dross sump, as shown at (a) in the illustration overleaf, may



Traps are used to prevent oxides or foreign bodies from entering moulds. In the above, three varieties are shown, (a) a dross sump (suitable for small castings) where the collection is made; (b) and (c), dross traps which prevent the dross from entering the mould and allow it to be collected in the sump.

suffice for a small casting. The type shown at (b) is more effective; the dross, being lighter than the metal, is trapped at X. Alternatively the in-gate may be led into a riser or dummy riser as shown at (c). To ensure the riser filling and so trapping the dross, the outlet must be smaller than the inlet.

DRY AREA. An enclosed cavity sometimes formed within the base of the external walls of a building as a precaution against ground damp. The enclosed space can be ventilated by inserting air bricks or gratings at intervals above ground level in the outer wall; but special care should be taken to keep out all refuse, vermin etc. A dry area is sometimes contained within the base plinth of the wall of a building.

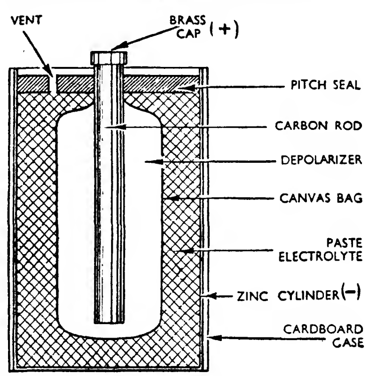
DRY CELL. A variation of the Leclanché cell (q.v.). Batteries of this type of cell are used largely as portable sources of electricity for such things as electric torches. The cell is not really dry but contains a paste. The outer zinc case forms the negative electrode while a central carbon rod is the anode. The porous pot is replaced by a canvas bag containing a depolarizer, and this is surrounded by a paste containing sal-ammoniac. The construction is shown in the diagram.

DRY-SAND MOULDING. A method of moulding similar to that employed for green-sand moulds, with the exception that the faces of moulds are generally coated with a refractory paste, and the moulds are thoroughly dried, by heating in a special stove, before the metal is cast. Dry-sand moulds are much stronger than those made in green sand; consequently there is less likelihood of sand being washed away from the mould faces and becoming mixed with the metal, so causing defects in the castings produced. Moreover, since the moulds contain but little moisture, the possibility of the metal becoming chilled as it enters the mould is considerably reduced.

Dry-sand moulding is quicker than green-sand because, owing to the greater strength of the sand, less reinforcement is required. Extra expense is incurred, however, in the drying process; in the provision of a greater number of moulding boxes, necessary owing to the time-lag between moulding and casting; and in the extra space required for the drying stoves.

DUAL CONTROL. Duplication of the controls for the use of a second pilot in training aircraft and most large long-distance machines. The control column and rudder bar are duplicated, as are the engine controls, unless the pilots sit side by side, in which case the engine controls are usually placed centrally so as to be accessible to both pilots.

DUAL IGNITION. A combination used in petrol engines, of battery-and-



Section diagram showing the construction of a dry cell. The depolarizer is black manganese dioxide and other chemicals; a white paste containing sal ammoniac acts as the electrolyte.

coil and magneto ignition. Coil-ignition systems are most efficient for starting and at low engine speeds, but the quality of the spark falls off as high engine speeds are attained; magnetos, on the other hand, produce a much better spark at high engine speeds.

By incorporating both systems the advantages of each are obtained. Dual-ignition systems are employed on petrol engines where great reliability is required, for, should one system fail, the other is available.

In aero engines, the magneto system is almost universal and is usually completely duplicated, including the provision of two plugs per cylinder.

DUBBING OUT. The levelling-out of hollow places in a wall before the finishing coat of plaster is applied. The straight-edge is tried out over the surface, vertically, horizontally and at various angles, and the hollow spaces marked. Plaster is then laid on until the whole surface is even.

DUCT (Auto-Engineering). In internal-combustion engines the term denotes the carburettor air-intake duct which conveys a supply of air from the intake to the carburettor.

DUCT (Building). Ducts are cavities, formed within the thickness of the walls of a building, or secreted within a building, for housing service pipes and conveying air to or from the rooms. They are usually rectangular in section.

Sheet-metal ducts are chiefly used as the medium for conveying air in mechanical systems of heating and ventilation; the housing or covering of these ducts has given rise to many changes in the construction of buildings (see AIR DUCT and VENTILATION).

DUCTED COOLING, see COOLING.

DUCTILITY. A property of metals measured by the increase in length produced in breaking a tensile test piece, and expressed as a percentage of the original length of the test piece. To obtain comparable results with test pieces of different sizes, the length over which the elongation is measured must bear a constant relation to the diameter of the test piece. The generally applied formula is:= $G=4\sqrt{A}$ where G=gauge length and A=area of cross section of the test piece. The measurement of elongation must always include the actual fracture of the test piece. See TENSILE TEST.

DULL EMITTER. A radio valve whose cathode is able to liberate sufficient electrons at a dull-red heat. See RADIO VALVE.

DUPLEXING. The use of two steel-making processes in converting raw materials to a finished steel. Various methods of duplexing are possible, because each different type of furnace —Bessemer, open-hearth, electric-arc, electric-induction—is considered as one treatment, while acid practice is further differentiated from basic. A typical example is to part-make steel in the Bessemer and finish the process in the open hearth. The essential idea behind duplexing is to get the well-known advantages of each type of furnace—Bessemer for speed of operation, open hearth for quantity and control, and electric furnaces for high quality.

DURAIN. A constituent of many coals; it exists in solid, grey, dull bands and has a fine granular structure. See COAL.

DURALUMIN. A well-known aluminium alloy. The usual range of composition is: copper, 3·5 to 4·5 per cent; magnesium, 0·4 to 0·7 per cent; manganese, 0·4 to 0·7 per cent; silicon, about 0·4 per cent; and iron, up to 0·5 per cent. Copper, magnesium and manganese are the alloying elements, silicon and iron being the impurities.

The alloy may be hot-worked at about 450 deg. C. and is suitable for making forgings, stampings, pressings, bars, sheet, tubes, rivets etc. After hot-working, a limited amount of cold-working may be applied. Heating to 500 deg. C., followed by quenching, softens the alloy, but within a short time age-hardening sets in, resulting in a gradual increase in strength over a period of several days. Full softening without subsequent

age-hardening is obtained by heating-up to 350 to 380 deg. C. In the fully hardened state duralumin has a tensile strength of 27 tons per sq. in. with 20 per cent elongation.

DUTCH METAL (Paint). Alloys of copper and aluminium in which their respective proportions are varied to give different shades of colour from pale to deep gold. They are supplied in leaf form, from 3 to 5 in. square, contained in books of 25 leaves, and are used as a substitute for gold leaf in the preparation of the ground of embossed and textured materials which are to be further enriched by the use of coloured transparent lacquers.

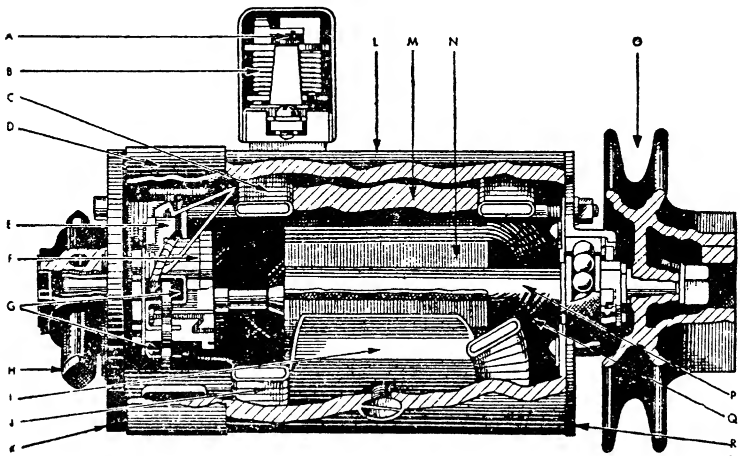
The ground is first rendered non-absorbent by painting and is then coated with japanners' gold size; when this is tacky, the leaves are laid upon the surface and pressed with a soft pad. All leaf metals containing copper must be protected with a coating of lacquer or cellulose in order to prevent the formation of black oxide of copper.

DWELL, see CAM.

DYNAMICS, see MECHANICS.

DYNAMIC STABILITY, see LONGITUDINAL STABILITY.

DYNAMO. The name given to an electric generator of the D.C. type. It finds special application on a motor vehicle in charging the battery. In this case the drive from the engine may be by shaft or belt. When the latter is used the cooling fan is sometimes bolted on to the driven pulley O as shown in the diagram. The yoke or body L carries the pole pieces M and I, on which are wound the field windings C and J. These windings may be connected so that the armature current passes through them (series winding), or so that only a portion of the current passes through them (shunt or parallel winding), or a combination of the two (compound winding).



AUTOMOBILE DYNAMO IN SECTION

A, cut-out contact points. B, cut-out coils. C, field winding. D, commutator cover. E, regulator brush. F, commutator. G, main brushes. H, oil reservoir. I, pole piece. J, field winding. K, end plate. L, generator yoke or body. M, pole. P, armature winding. R, end plate.

To prevent the battery from discharging through the generator when the voltage in the latter falls, an automatic switch or cut-out is fitted, so that the contact points A open when the current in the cut-out B is insufficient to hold them together by electro-magnetic attraction. When the points open, the connexion to the

battery is broken, to prevent the battery discharging through the generator.

When the armature windings Q are rotated between the poles M and I, energized by the windings C and J, a voltage is generated in the armature windings by electro-magnetic induction. The armature windings are connected to a commutator F, which consists of a number of copper segments, each insulated from the other, the purpose of which is to deliver direct-current to the main carbon brushes G, the positive brush being connected to the positive terminal of the battery through the cut-out, the negative brush being earthed or vice-versa on an earthed-positive system. A third, or regulator, brush E is incorporated to prevent the voltage rising to too high a value as the armature speed increases with that of the engine. The end-plates R and K are bolted to the body of the generator, and incorporate bearings to support the armature shaft P. See D.C. GENERATOR.

DYNAMOMETER. A type of electrical measuring instrument consisting of fixed and moving coils. The moving coils may turn a pointer over a scale, or there may be a torsion head, in which case the torsion head is turned to restore the deflection to zero, the amount of twisting being measured.

DYNE. Unit of force in the c.g.s. or metric system, defined as force which, acting on 1 gram, produces an acceleration of 1 cm. per second per second.

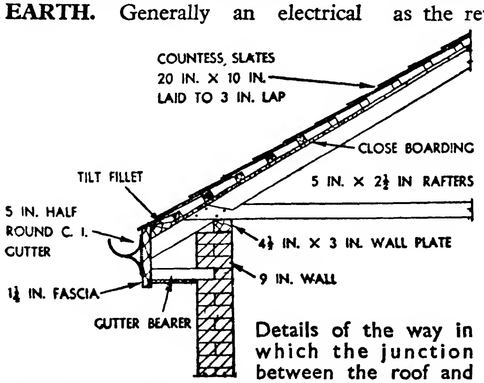
EARING (Sheet-Metal Work). The presence in deep-drawing operations of cups having a pronounced waviness around the rim, the components being thereby defective and rejected. Earing may be divided into two classes: (a) single or double tup, which may be caused by an error either in press-tool design or gauge variation across the width of the strip, and (b) a symmetrical profile showing four or six ears, caused by structural fault in the metal itself. See CONTOUR CONTROL.

EARTH. Generally an electrical connexion to the earth itself by means of buried copper plates or a rod. It is usually considered as a *low potential* point of reference. More loosely, the low potential or common end of certain electrical circuits or networks. For another use of the term, see EARTHED SYSTEM.

EARTH RETURN, see EARTHED SYSTEM.

EARTHED SYSTEM. An electrical distribution system which utilizes the earth, or a mass of metal, such as the chassis of a motor vehicle, as the return conductor. The earth, or the metal work of the vehicle, then constitutes an earth return.

EAVES. The lower and horizontal edge of an inclined or pitched roof surface, generally overhanging the walls of a building. Its practical purpose is to close the junction of the rafters and the wall construction, and to provide for the disposal of the rain water flowing down the roof surface. If the rafters are left exposed, the eaves are termed *open*



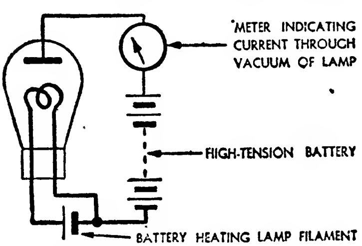
Details of the way in which the junction between the roof and the wall of a building is closed by the construction of boxed eaves. A gutter is attached to the fascia.

eaves; but when the rafters are concealed by woodwork, the eaves are termed *boxed* eaves. The incorporation of an efficient gutter is an important item in the design of eaves.

EBONITE, see VULCANITE.

EDDY CURRENT. An electric current circulating in a closed path within a conductor, and induced by a changing magnetic field or by motion of the conductor relative to the field. Electricity meters usually have a metal disk which rotates between the poles of a permanent magnet, the arrangement acting as an eddy-current brake. Synonym: Foucault Current. See IRON LOSS.

EDISON EFFECT. Discovery by Edison in 1884 that an electric current



If a metal plate is introduced into a vacuum tube containing a heated filament, and the plate is made positive relative to the filament, a current will flow between the filament and the plate.

will flow between an independent cold electrode and a heated filament in an evacuated bulb. This effect is the basis of the radio valve (q.v.).

EFFICIENCY. Symbol: η. The ratio of the output to the input of an electrical machine or apparatus. Both must be in the same units, e.g. for a motor, mechanical output must be converted to electrical units such as watts, or electrical input to mechanical units such as horse-power. Efficiency is usually expressed as a percentage.

EFFLORESCENCE (Building). The development of various calcium salts upon lime-plastered and brick surfaces. Lime-plaster and mortar are liable to contain free lime and sand contaminated with non-metals. Access of water to the fabric through leaky gutters, porous bricks or imperfect damp courses, brings about chemical reactions which produce salts; these make their way to the surface and force-off any superimposed material.

The only effective cure is to stop the penetration of moisture at its source and allow time for the fabric to dry. Superficial treatment cannot prevent the development of these salts; it may, indeed, hasten the disintegration of the whole fabric.

EFFLORESCENCE (Chemistry). The property of some crystals containing water of crystallization of losing part of the water by evaporation and so becoming powdery. Washing soda, $Na_2CO_3.10H_2O$, has this property.

EJECTOR EXHAUST. An exhaust system designed to achieve an appreciable additional thrust on aircraft by directing the flow of exhaust gases backwards. It may consist of short exhaust pipes from each cylinder or the gases may be discharged from the cylinders into a common manifold which has one or more backward-facing exits. It is usual to taper the exhaust pipes towards the exit in the form of a nozzle.

By this means, a back pressure is built-up in the pipes or manifold which forces the gases out at a higher speed than would otherwise be the case, and so a greater thrust is produced. This, however, may have an adverse effect as the manifold back pressure reduces the power delivered to the propeller shaft by the engine. But it is possible to determine a value for the optimum exhaust nozzle area at which the thrust horse-power obtained from the ejector exhaust exceeds the power loss due to back pressure by the largest possible amount.

EKKI, see IRONWOOD.

ELASTIC GRINDING WHEEL. A thin disk obtained by mixing abrasive powder with shellac as the chief bonding material; when rotated at high speed, such disks can be used as grinding wheels and are now employed for cutting steel and in an increasing variety of manufacturing operations. Shellac is very elastic, so

that disks made by this means, though very thin, can be used with safety.

In practice, wheels as thin as $\frac{1}{32}$in. have been successfully used. They are employed in workshops instead of shears or hacksaws for cutting off lengths of pipes and bars, thin brass or tin sheets, and similar materials, because they do not involve any difficult setting-up operations for holding large or awkwardly shaped pieces to be cut. Thicker elastic grinding wheels are used for grinding gear-wheel teeth, sharpening wood-working tools etc.; they also give good results for roll grinding, where a very high degree of surface polish is needed, and are also used for producing smooth, polished surfaces in cutlery.

ELASTICITY. The capacity of a substance to return to its original shape or volume after being deformed by external forces. The restoring force caused by the deformation is called the stress; the deformation is the strain. The ratio of stress to strain is a measure of the elasticity, and is called the coefficient of elasticity. Most metals and alloys are elastic to a certain degree, but many behave in a plastic manner if the stress exceeds a certain value, known as the yield point (q.v.).

E-LAYER. One of the electrified layers in the ionosphere (q.v.). See RADIO-WAVE PROPAGATION.

ELECTRICAL ETCHING. A process used in place of the more usual ferric-chloride bath for etching copper plate for printing purposes. The plate is exposed, inked, developed and blooded in the usual way, then electrolytically etched in the anode circuit of an electrolytic bath. The unprotected non-printing parts are removed at a rate which is controlled by the amount of current passed.

ELECTRICAL UNITS. Unlike the British systems of weights and measures, electrical units follow a metric system. Each unit may be multiplied or divided by powers of 10 to form a larger or smaller unit convenient for the size of the quantity measured. To indicate this change a prefix is added and these prefixes are common to all units, except where convenience in pronunciation leads to the dropping of a vowel. The prefixes in common use are shown in order of size in Table 1. The smallest units are at the top.

TABLE 1.

PREFIX	MULTIPLYING FACTOR	SYMBOL
Micromicro-, or Pico-	10^{-12}	$\mu\mu$ or p
Micro-	10^{-6}	μ
Milli-	10^{-3}	m
Kilo-	10^{3}	k
Mega-	10^{6}	M

Taking the watt as an example, this is the way in which the scheme works. For such things as electric lamps, the watt is itself a convenient unit, for example, a 60W. lamp. An electric fire may be rated at 2000 watts and this is easier to write as 2 kilowatts or 2kW., while the output of a power station might be 50 million watts which is expressed as 50 megawatts, or 50MW. At the other extreme, the power required to operate a relay or that taken by the grid of a valve may be measured in milliwatts, mW, or in microwatts, μW.

The whole range is not normally needed in many cases. For example, inductances do not usually go beyond the henries range, while a capacitance measured in farads is a very large one.

It will be noticed that the prefix symbols as well as the prefix names are common to all units.

One of the cases where it is necessary to drop a vowel is the ohm. Thus a million ohms are a megohm, not a mega-ohm, and similarly for microhm instead of micro-ohm.

A noteworthy point, which is brought out by the table, is the very wide range over which electrical measurements are spread. It is necessary, for example, to be able to measure resistances in microhms

ELECTRICAL UNITS—TABLE 2

Quantity	Symbol for Quantity	Phonetic Equivalent	Unit	Symbol for Unit
Current	I		Ampere	A
Potential Difference	E. or V.		Volt	V
Resistance	R.		Ohm	Ω
Inductance	L.		Henry	H
Capacitance	C.		Farad	F
Reactance	X.		Ohm	Ω
Impedance	Z.		Ohm	Ω
Conductance	G.		Mho	℧
Susceptance	B.		Mho	℧
Power	P.		Watt	W
Work			Watt-hour	Wh
Magnetic Flux	Φ	"fie"	Line Maxwell	
Magnetic Flux-Density	B.		Gauss	
Magnetizing Force	H.		Oersted	
Permeability	μ	"mew"		
Magnetomotive Force	F.		Gilbert	
Permittivity	κ	"capper"		
Resistivity	ρ	"roe"		
Quantity of Electricity	Q.		Coulomb Ampere-hour	
Efficiency	η	"eater"		
Phase Angle	φ	"fie"	Degrees Radians	
Reluctance	S.			

and insulation resistances in thousands of megohms, not to mention all possible values between these extremes.

For convenient reference the common electrical and magnetic quantities, together with the units in which they are measured, are summarized in Table 2.

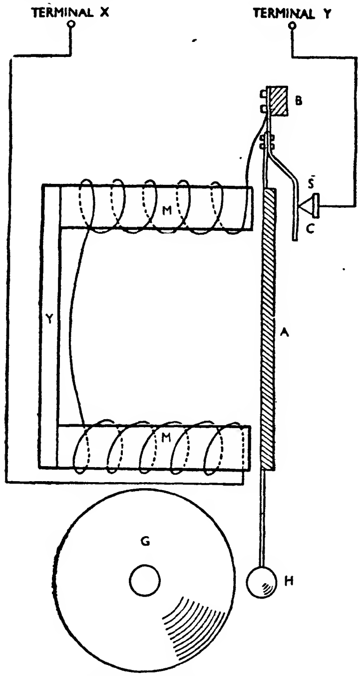
ELECTRIC BELL. A signalling device employing a gong and an electrically operated hammer. The parts of a bell are shown in a diagram on the opposite page.

Current led in at terminal X flows through the windings M on the magnet, then, by way of the block B, the spring S and the adjustable contact C, back to terminal Y. The magnet then attracts the armature A so that the hammer H strikes the gong G. In doing this it breaks the contact at C and the spring restores the hammer to the off position. This action renews the contact at C and the sequence of operations continues as long as current is supplied.

ELECTRIC FIELD. The space within which an electrically charged body experiences a force. The force may be due to another charged body or to a changing magnetic field. See COULOMB'S LAW.

ELECTRIC FLUX-DENSITY. Symbol, D. The number of electrostatic lines of force crossing a unit area perpendicular to the lines of force.

ELECTRIC-RESISTANCE BRAZING, see BRAZING.



Principle of operation of an electric bell is shown in the diagram, which should be studied in conjunction with text. The contact C is usually adjustable by means of a screw which in some designs can be locked in position.

ELECTRIC STRENGTH. The greatest electric potential gradient, usually expressed in kilovolts per mm. which a dielectric can withstand without breaking-down. See POTENTIAL GRADIENT.

ELECTRIC WELDING. Joining two pieces of metal by heating them with an electric current to the correct temperature so that the metal becomes soft and may be united by pressure. Either of two systems may be followed: *electric-resistance* welding or *electric-arc* welding.

In resistance welding, the two pieces to be joined form a resistance in an electric circuit through which so large a current is passed that fusion, with consequent welding, of the two pieces takes place.

The welding machine is provided with electric leads coupled to clamps; these act as terminals for a large current which is passed through at comparatively low voltage. When the clamps are brought together, current flows through the work, which thus completes the electric circuit. A feature of the method is that the interior of the parts to be welded is raised to welding temperature before the external surfaces, heat being generated so quickly that the energy-loss is insignificant. This method is used for joining forgings and stampings, e.g., in the construction of motor-cars.

In arc welding, the part to be welded forms one terminal, being connected to the positive lead of the circuit; the negative lead is coupled to a metallic electrode, so that the current traverses the small air gap between the electrode and the workpiece. An exceedingly intense heat is generated across the gap, since the air, being a poor conductor, offers a high resistance to the passage of the current.

The temperature of the arc is about 6330 to 7230 deg. F. The arc itself is initiated by momentarily touching the workpiece with the electrode and then withdrawing it. The resulting heat is sufficient to make the metal melt entirely away, or fuse with another piece of metal—whichever may be desired. This process is also used for severing metals by the action of the arc. Electrodes are often coated with a flux to prevent the formation of unwanted impurities such as nitrides, oxides etc.; in some cases this helps to keep the materials in the electrode in permanent combination with those of the workpiece, and to cause the weld metal to cool more slowly.

ELECTRIC WIRING, see WIRING.

ELECTROCHEMICAL EQUIVALENT. The mass or amount of a substance undergoing electrochemical change per coulomb, electrochemical action being proportional to the number of coulombs passed.

ELECTROCHEMICAL SERIES. A series in which the various chemical elements are arranged in such a way that each element is electronegative

to those preceding it, and electro-positive to those following it.

ELECTROCHEMISTRY. A branch of physical chemistry dealing with the effects of the electric current in chemical transformations.

ELECTRODE. A conductor by means of which an electric current enters or leaves a liquid or gas. The term is also used for a metal or carbon rod from which an arc is struck, in the practice of electric-arc welding. See ELECTRIC WELDING.

ELECTRO-DEPOSITION. The method of coating an object of one metal with another by making it the cathode in an electrolyte. The electrolyte usually contains a salt of the metal to be deposited together with other constituents to improve the deposit. The anode is either of the same metal as the deposit, or of an inert metal, e.g. lead anodes which are used in chromium plating.

Electro-deposited coatings are applied to improve the corrosion or wear resistance of the underlying metal, or for purely decorative purposes. An increasing use is for building-up worn or wrongly machined parts. The source of power may be a rectifier or generator giving direct current at a pressure of about 6 volts or more, and an amperage suited to the size of the plant and the quantity of work being plated. Plating-current densities usually range from 8 to 40 amps per sq. ft.

The metals most commonly deposited are nickel, chromium, copper, silver, gold, zinc, cadmium and lead. Chromium is generally deposited over a nickel undercoat. The thickness of the coatings is usually of the order of 0·0001 to 0·002 in. under ordinary commercial conditions.

It is possible to deposit alloys (e.g. brass or speculum metal) electrolytically from suitable solutions. Successful electro-deposition necessitates the most scrupulous care in the pre-treatment and cleaning of the basic metal, and the use of suitable plating solutions depending on the nature of the latter metal. Both the underlying metal and the plated deposit generally have to be buffed or polished when decorative coatings are applied. See ELECTRO-GALVANIZING and ELECTROLYSIS.

ELECTRO-GALVANIZING. The electro-deposition (q.v.) of zinc upon ferrous metals to protect them from corrosion. Zinc applied by electro-deposition has better resistant properties than zinc applied in molten form.

The solution of electrolyte used for depositing zinc is composed of an acid sulphate or an alkaline cyanide salt. Articles to be coated with zinc are first freed from all dirt and grease, then attached to the cathode or negative (−) of a cell, of which the anode or positive (+) is of zinc in an electrolyte of zinc salt. During electrolysis the zinc ions are discharged at the cathode and deposited on the article to be plated, while the cyanide ions discharged at the anode, with which they combine, re-form zinc cyanide.

There are two other methods of galvanizing, i.e., hot galvanizing, in which molten zinc is covered with a flux of sal-ammoniac, the objects to be coated being dipped and drawn through the molten zinc; when withdrawn they are covered with a coating of metal; and vaporization, such as sherardizing (q.v.) in which articles to be coated are heated in contact with pure zinc-dust and/or the oxide of that metal, rotated in a closed retort and baked to a temperature of 720 to 810 deg. F., when zinc becomes vaporized and adheres to iron or steel articles.

ELECTROLYSIS. The conduction of electricity by ionic movement in a liquid. This movement causes chemical changes such as the liberation of gases or the deposition of metal from a solution, as in electroplating. By the electrolysis of fused salts of aluminium, magnesium, sodium, potassium, calcium and barium, these metals are prepared.

The electrolysis of metallic salts dissolved in water is made use of in two ways, in the production of the metal and in its purification. As an example of the first, crude copper ores, if suitable for the process, are

dissolved in dilute sulphuric acid and a solution of copper sulphate is obtained. This solution contains ions of copper and sulphate. The copper ion is an atom of copper positively charged with electricity; the sulphate ion is a negatively charged SO_4 group.

When a current of electricity is passed through a solution of copper sulphate in which are two copper electrodes, one of these, the cathode, becomes negatively charged, and the other, the anode, positively charged; as a positively charged body attracts a negatively charged body and vice versa, the cathode attracts the copper ions and the anode attracts the sulphate ions; the copper ions move to the cathode, and when they reach it they give up their positive charge of electricity and become atoms of copper which are deposited on the cathode. Simultaneously the sulphate ions travel to the anode and give up their negative charges. When this happens, the sulphate ion breaks up a molecule of water, taking two atoms of hydrogen to form a molecule of sulphuric acid and liberating an atom of oxygen which unites with another oxygen atom to form a molecule of oxygen.

The copper ion is called a *cation* because it is liberated at the cathode, the sulphate ion is called an *anion* because it is attracted to the anode. Zinc, copper and cadmium are made on a large scale by such an electrolytic process.

Copper, silver, gold, nickel and bismuth are examples of metals commercially refined by electrolysis. When nickel is so refined, a sheet of pure nickel is made the cathode and a thick slab of impure nickel the anode. When these are connected up to the supply of electricity, pure nickel is deposited on the cathode, and simultaneously the impure metal dissolves in the dilute sulphuric acid, some of the impurities in the metal dissolving, the others being precipitated as a sludge. The impurities, which may be very valuable metals, are afterwards recovered both from the sludge and from the acid solution.

Electro-plating is a special kind of electrolysis and is employed to make protective coatings on metals that are easily corroded, for instance iron and steel. Nickel and chromium are the most popular of such coatings.

Faraday's law states that the weight of any substance liberated or deposited is proportional to current, time and a number called the electrochemical equivalent, which, in turn, depends on the substance concerned. See ATOM, ELECTROLYTE and ELECTRON.

ELECTROLYTE. Any conducting medium or solution that undergoes chemical decomposition when an electric current passes through it as a result of the movement of ions. For example, when copper sulphate ($CuSO_4$) is dissolved in water it splits up into copper (Cu) ions carrying negative charges. When two electrodes are dipped into this solution and a voltage is applied to them, the copper ions are attracted by the negative electrode and are there discharged while the electrode becomes copper plated. The sulphate ions are attracted to the positive electrode where they too are discharged and the sulphate ion combines with hydrogen (H_2) from the water (H_2O) to make sulphuric acid (H_2SO_4), leaving spare oxygen (O) which appears as bubbles. This electrolytic conduction is quite different in mechanism from the ordinary electronic conduction.

For electro-deposition, an electrolyte is composed mainly of a salt of the metal to be deposited and additions of such substances as gelatin or glue, which are known to improve the colour, adhesion, plasticity and grain size of the coating, and also to allow higher current densities to be obtained. These substances are known as colloids or addition agents.

Liquids which do not conduct electricity, or do so only with considerable difficulty, such as water, benzine, aqueous solutions of alcohol or sugar, are non-electrolytes, while those which are good conductors, such as aqueous solutions of hydrochloric acid or sodium chloride, are electrolytes. There are also "weak" electro-

lytes. These are the weaker acids such as sulphurous acid, acetic acid, carbonic and boric acids and oxalic acid, and weaker bases such as ammonium hydroxide. See ELECTRODE and ELECTROLYSIS.

ELECTROLYTIC CELL. A general term for any combination of electrolytes and the necessary electrodes. It includes primary cells, electroplating baths etc. See PRIMARY CELL.

ELECTROLYTIC CLEANING. The removal of grease and foreign bodies from metal surfaces by electrolysis. The material to be cleaned is made the cathode of a low-voltage direct current, while the electrolyte consists of a dilute solution of caustic alkalis. De-greasing (q.v.) and cleaning result from the active evolution of hydrogen at the cathode, plus the emulsifying and saponifying actions of the alkalis present in the solution. This method is generally employed for the continuous de-greasing of steel strip and for cleaning fabricated articles before pickling and plating. The substances widely employed are phosphates, hydroxides and silicates of the alkali metals. Anodic cleaning and alternating-current cleaning are also used. Another method of electrolytic cleaning is that carried out in fused salts as distinct from aqueous electrolytes.

ELECTROLYTIC CONDENSER. A type of electrical condenser (q.v.) in which the dielectric is a very thin layer of aluminium oxide on an aluminium electrode. The other electrode is an electrolyte in the form of a liquid or paste. Owing to the extreme thinness of the film, large capacitances may be obtained for a relatively small total volume. Care is needed in using these condensers to ensure that the voltage is not too high and that, if the D.C. variety of condenser is concerned, it has the correct polarity.

ELECTROMAGNET. A magnet which acts effectively only when an electric current is passed through its windings (see, for example, ELECTRIC BELL). There will generally be some small magnetic effect when the current is not flowing owing to the residual magnetism (q.v.). See also ELECTROMAGNETISM.

ELECTROMAGNETIC INDUCTION. The effect by which an electromotive force is produced in a conductor by a changing magnetic field or by motion relative to a magnetic field. See ELECTROMAGNETISM.

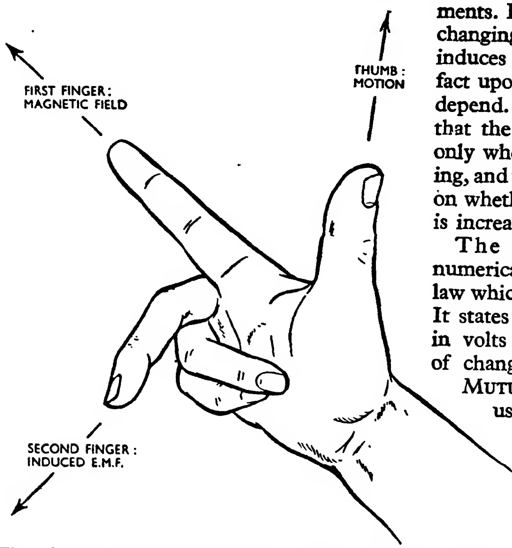
ELECTROMAGNETISM. The relations between electric currents and magnetic fields are the foundation of all electric generation, and of most of the utilization of electrical power, for all generators and motors, with very few exceptions, are electromagnetic machines. It is possible to construct practical electrostatic generators, but there seems to be no possibility of an electrostatic motor.

A straight wire carrying a current produces a magnetic field in which the lines of force take the form of concentric circles round the wire. This field may be detected by means of a compass needle and it will be found that the north pole of the needle is deflected towards the left hand of an imaginary individual swimming along the wire in the same direction as the current, in such a way as to be looking at the needle.

If the wire is placed in another magnetic field and is free to move, it will do so because it experiences a force depending on its length, the current, and the strength of the magnetic field. It thus forms an elementary electric motor.

When the straight wire is coiled up to make a solenoid (q.v.) the magnetic effects are more concentrated. It now behaves rather like a bar magnet and will attract a piece of iron. The addition of an iron core permits the available magnetizing force (q.v.) to produce much more flux and the magnetizing effects are still further increased. The resulting electromagnet is used in electric bells, buzzers, some relays, magnetic clutches, and as a lifting device for iron, either as described, or in modified form.

If, instead of being allowed to move under the influence of the field, the straight wire mentioned earlier is



Thumb, first finger and second finger of the right hand are extended mutually at right-angles. If the thumb indicates the direction of motion of the conductor relative to the field, and the first finger points in the direction of the field, then the second finger points in the direction of electromotive force generated or induced.

moved forcibly against the field, then work is done, which reappears in the form of an e.m.f. in the wire.

Assuming that there is a closed circuit, this e.m.f. results in a current and the arrangement constitutes an elementary generator.

The direction of the current is fixed by the right-hand rule. To apply this rule, the thumb and first two fingers of the right hand are extended at right-angles as shown in the diagram where an explanation is given of how the rule is applied.

By using the left hand in an exactly similar way, the direction of motion of a current-carrying conductor in a magnetic field may be found. It should be noted that the rule gives the direction in which the conductor moves. If the conductor is fixed, the magnet moves in the opposite direction.

The discovery that a current could be generated by the relative motion of a wire and a magnetic field was one of Faraday's outstanding achievements. He also discovered that a changing current in one circuit induces a current in another, a fact upon which all transformers depend. It is important to note that the induced current occurs only when the current is changing, and that its direction depends on whether the changing current is increasing or decreasing.

The effects were given numerical significance in the law which bears Faraday's name. It states that the induced e.m.f. in volts is 10^{-8} times the rate of change of interlinkages (see MUTUAL INDUCTANCE). It is usual to prefix a negative sign, in accordance with Lenz's law (q.v.), which states that the direction of an induced e.m.f. is such as to oppose whatever change caused its production.

ELECTROMETER. An electrical device which electrostatically measures potential differences. Such an instrument normally utilizes the force of attraction and/or repulsion between charged bodies. See COULOMB'S LAW.

ELECTROMOTIVE FORCE (e.m.f.). Symbol: E. The potential difference produced by an electrical source when no current is being drawn from it. The practical unit of e.m.f. is the volt. See STANDARD CELL.

ELECTRON. A "weightless particle of electricity" possessing a negative electric charge equal to $1{\cdot}58 \times 10^{-19}$ coulomb. Electrons in motion constitute an electric current and one ampere represents a rate of flow of $6{\cdot}28 \times 10^{-18}$ electrons per second. The electron is the smallest quantity of ordinary negative electricity. It behaves sometimes as a wave, sometimes as a particle; it has the characteristics of both, but is so far removed from our ordinary experience that the human mind is incapable of making a mental picture of it. An electron has a small mass, only $1/1840$ that of a

hydrogen atom, and can, in suitable circumstances, travel almost with the speed of light. Every chemical element consists of a central positively charged nucleus surrounded by a mass of electrons—one for each positive charge on the nucleus—the electrons being placed, not at random, but at what are called different energy levels. They may be symbolized by concentric spheres in which they are free to revolve round the nucleus. If the atom is heated the electrons are driven further away from the nucleus, and may indeed be driven quite out of its neighbourhood. See ATOM.

ELECTRON MULTIPLIER. A multi-electrode radio valve in which the final anode current includes electrons of both primary and secondary emission. Secondary emission occurs when electrons impinge on a suitable target electrode with such velocity that they dislodge and liberate electrons from the material of the target. The emission so evoked is roughly proportional to the primary emission which is the cause of it. With correct circuit design it is possible with such devices to obtain very large degrees of amplification.

ELECTRONEGATIVE ELEMENTS, see ELECTROCHEMICAL SERIES.

ELECTRON OSCILLATIONS, see BARKHAUSEN OSCILLATIONS.

ELECTROPOSITIVE ELEMENTS, see ELECTROCHEMICAL SERIES.

ELECTROSTATIC GENERATOR. An electrical machine in which mechanical energy is converted into electrostatic energy. The Wimshurst machine is an example of this type of generator.

ELECTROSTATIC LINE OF FORCE. An imaginary line in an electric field which indicates the direction of the force on an electric charge at any point.

ELECTROSTATICS. The science which deals with the characteristics and behaviour of electrically charged bodies.

ELECTROSTATIC VOLTMETER. An electrical instrument which works on the electrometer (q.v.) principle. This type of instrument can be used on A.C. or D.C. In the latter case it takes no current and consumes no power, while in the former, very little of either.

ELECTROTYPE. A duplicate of a printing-process block, produced by the electro-deposition (q.v.) of copper on to a wax mould made from the original. It is preferred to a stereotype where a better-class pictorial reproduction of an original is required. See STEREOTYPE.

Also a name given to a printing process practised in Germany, which is similar to the Aquatone process. See AQUATONE.

ELEKTRON. A range of very light magnesium alloys with a specific gravity of about 1·8, only two-thirds that of aluminium, very widely used in aircraft construction. It burns with a dazzling, white light, but does not begin to melt until a temperature of about 1200 deg. F., the melting point of aluminium, is reached. It will withstand exploding gases and the combustion-chamber conditions of internal-combustion engines, in which it has been much used for crank cases, etc.

The chemical actions set up when Elektron comes into contact with running water, acids or acid solutions preclude its use with these substances without a protective coating. Elektron alloys, both cast and wrought, generally contain aluminium and zinc, with additions of manganese to enhance corrosion resistance. They are stronger than the aluminium-base alloys, and possess excellent machinability, high resistance to fatigue, high damping capacity and freedom from intercrystalline corrosion. Elektron is the registered trade name of Magnesium Elektron, Ltd., covering that firm's range of magnesium-base alloys.

ELEMENT. A substance that cannot be broken down to yield a simpler substance by the usual chemical methods. Almost all elements may be broken down by bombarding them with protons, neutrons and other small particles with high velocities

(see RADIOACTIVITY). The relative abundance of the chemical elements in the earth's crust is roughly as follows:

Oxygen	47·3 per cent
Silicon	27·7 „
Aluminium	7·8 „
Iron	4·5 „
Calcium	3·5 „
Sodium	2·5 „
Potassium	2·5 „
Magnesium	2·2 „
Titanium	0·5 „
Remainder	1·5 „

ELIMINATOR, see BATTERY ELIMINATOR.

ELLIOT AXLE, see AXLE.

ELM. A reddish-brown wood, fairly hard and heavy, and very tough, which shrinks and warps freely unless carefully seasoned. There are several species. Slash-sawn elm produces handsome figure. It is very durable, and is used for underground and exterior work. See TIMBER.

ELONGATION. The generally accepted measure of ductility. It is the increase in length of a fractured tensile testpiece, expressed as a percentage of the original gauge-length (2 in. or 8 in. in the case of sheet). Thus:

$$\text{Percentage elongation} = \frac{\text{increase in length}}{\text{original gauge length}} \times 100$$

A high elongation percentage usually denotes good ductility and drawing quality. Marked differences in the elongation values of specimens cut with their axes parallel to, at 90 deg., and at 45 deg. to the direction of rolling, are indicative of directional properties in a sample of sheet and other wrought material. See TENSILE TEST.

EM. Unit which is the basis of length and depth of a line of printer's type; equal to the square on the body of the type and varying according to the size used.

EMANATION. The former name of a radioactive gas emitted by radium; it is one of the rare inert gases and is now called radon (q.v.). See also RADIUM.

EMBOSSED WALL COVERINGS. Wall hangings with raised textures, often in imitation of weaving. The relief may be imparted to the finished paper when dry, in which case it is only slight, or it may be impressed upon the material during manufacture, when much higher relief can be obtained.

In either case the method is to pass the paper between rollers under pressure, the upper roller being incised with the design, while the lower is covered with soft, felt-like material to take the impression. Embossed materials may also be obtained in panel form, with designs similar in character to plaster work and of considerable depth.

All these materials are applied with good, stiff flour paste in the same manner as in paperhanging. The paste is worked well into the fabric without soaking, undue wetting, or leaving too thick a film of paste; the hanging is then placed in position and beaten into contact with the bristles of a putting-on brush. *Lincrusta*, a trade name given to a plastic material for covering walls, differs from most embossed materials in that it resembles linoleum in composition and the relief is mounted upon a canvas or paper backing to make it solid. The relief is never very high, but its solid character enables it to stand up to rough usage; it is therefore a satisfactory material for covering dados and wainscoting in passages.

EMERALD GREEN. A bluish-green of very fine hue, which, owing to its poisonous character, is not much used except as an insecticide. Its place has been taken by colours called emerald-tinted greens, which are combinations of blue and yellow pigments precipitated in one operation or by pigments obtained by fixing a dyestuff upon an inert base.

E.M.F. Abbreviation for Electromotive Force (q.v.).

EMISSION. In a radio valve, the liberation of electrons from a heated cathode (primary emission) or from some other electrode (secondary emission). Thermionic or primary emission occurs when a metal is heated to a sufficiently high temperature. Secondary emission takes place

when high velocity electrons strike a metal and dislodge other electrons.

In any conductor, there are free electrons moving about at a rate determined by the temperature of the conductor at whose surface there is an electrostatic restraint on movement. At a sufficiently high temperature, these electrons, owing to their increased velocity, have enough energy to overcome this surface restraint and leave the metal. The energy that an electron must have to do this is known as the *work function* of the metal.

The only pure metal emitter of any importance is tungsten which can be heated sufficiently without melting. Other metals, though better emitters, melt at a relatively low temperature. It is, however, possible to coat tungsten with a thin layer of another metal and thus take advantage of its properties. It has been found that thorium is probably the most useful in this respect. The oxides of some of the alkaline earth-metals, notably strontium and barium, emit copiously at only a dull-red heat and are now extensively used for coating base-metal filaments.

Secondary emission, use of which is made in electron multiplier tubes, is determined by the work function of the cold target and the velocity of the primary electrons.

EMPENNAGE. The rear unit of an aircraft, consisting of tailplane and elevator for longitudinal stability and control, and fin and rudder for directional stability and control. Two of the most common forms of empennage are shown in the illustration.

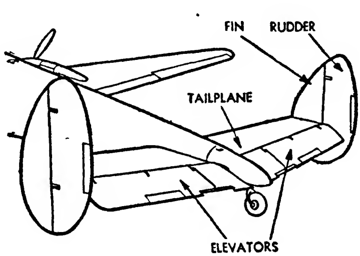
EMULSIFYING AGENTS, see EMULSION.

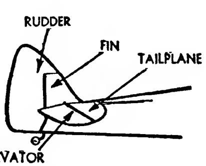
EMULSION. The name given to an intimate mixture of two liquids that are not mutually soluble to form a transparent liquid. Oil and water, or oil and vinegar, are examples of liquids that will not mix to form a clear liquid; the heavier one will sink to the bottom. If two such liquids are agitated together for a long time they can be made to form a fairly permanent mixture, which will become quite permanent if a gum or some other substance is added. Such additions are called emulsifying agents.

An emulsion consists of minute drops of one liquid floating in another, and two varieties of emulsions can be made—drops of oil floating in a watery solution, and drops of a watery solution floating in oil. Mayonnaise is a familiar example of an emulsion; other examples are those used for medicinal purposes, and for some washable distempers.

ENAMEL. A form of paint combining the obscuring power of ordinary paint with the finish and lasting qualities of varnish. The pigments are ground in a partially oxidized drying oil, which may be reinforced by resins, and diluted with turpentine or white spirit during the process.

Enamels are made in grades to suit internal or external surfaces and the





Two most common forms of empennage are illustrated above. They consist of the tailplane and elevator and carry the responsibility of controlling the longitudinal stability of the plane.

best results can be obtained only if an enamel is used on the surface for which it was made. Full-gloss, semi-gloss and flat finishes are supplied in an almost unlimited colour range.

A surface to be enamelled must be prepared so that it is non-absorbent and perfectly even, with very fine granulation to assist grip. The enamel

is applied with fairly compact brushes in a full coat, well brushed-out and finished with heavy strokes. No attempt should be made to soften-off because the enamel itself will flow out and obliterate brush marks. The material should be stored, and the work executed, in a temperature of from 60 to 70 deg. F. Enamels are supplied ready for use and should never be diluted.

ENDOTHERMIC. A substance formed from its elements with the absorption of heat.

ENDOTHERMIC REACTION, see ENDOTHERMIC.

END PLAY. Lateral movement in a shaft; that is, movement along its axis as opposed to side play.

ENERGY. Capacity for performing work. It is measured in the same units as work. The erg (q.v.) is the C.G.S. (centimetre-gramme-second) unit of energy and is the amount of energy expended when a force of one dyne is exerted through a distance of one centimetre. The joule is the unit of energy in the practical system of units, one joule being equal to 10^7 ergs.

ENGINE, see INTERNAL-COMBUSTION ENGINE, STEAM ENGINE and TURBINE.

ENGLISH UMBER, see UMBER.

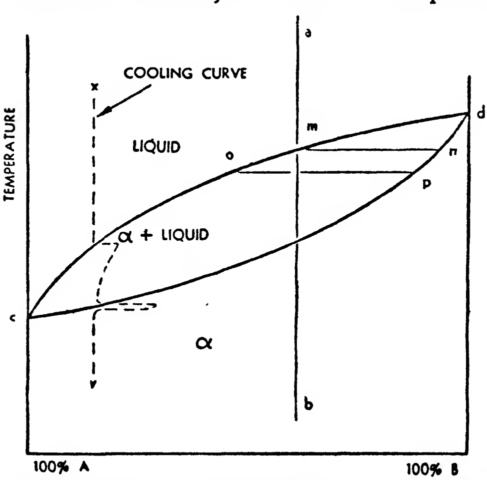


Fig. 1. Diagram for solid solutions A and B indicating the relative proportions of the two metals in an alloy. Line c, o, m, d, is called liquidus and line c, p, n, d, is called solidus.

ENGRAVING AND ETCHING. Processes by which blocks, plates and cylinders for printing purposes are made. Modern processes are almost entirely photo-mechanical, whether for relief, planographic or intaglio processes. See COLLOTYPE, LITHOGRAPHY, PHOTOGRAVURE and PRINTING.

ENTROPY. A measure of the randomness or disorder in the molecular arrangement of a substance. Entropy increases when a body is heated, and also when a regular, orderly motion is converted into random motion. The entropy increase at a temperature is the heat taken up by the body, divided by the temperature.

EQUALIZER, see EQUALIZING CONNECTOR.

EQUALIZING CONNECTOR. A connexion used in electrical armature windings in order to keep two or more points at the same potential. Synonym: Equalizer. See LAP WINDING.

EQUILIBRIUM. A condition in which no change tends to take place. For example, ice and water are in equilibrium at 0 deg. C.; a rise in temperature will cause the ice to melt, and a fall will cause more water to freeze. In alloys, a condition of true equilibrium is rarely obtained unless the rate of cooling from the liquid state is very slow. Indeed, the purpose of heat-treatment is often to prevent equilibrium being reached.

EQUILIBRIUM DIAGRAM. A diagram illustrating the changes that take place when an alloy solidifies and subsequently cools to room temperature. The simplest diagrams are of three main types; solid solution, eutectic and peritectic. A clear understanding of these will enable the reader to interpret the more complicated diagrams, in which

two or more of these types may be combined.

Solid Solution—The base line of Fig. 1 indicates the relative proportions of the two metals A and B in the alloy. At temperatures above the line c, o, m, d, all the alloys in the series are completely liquid; below c, p, n, d, completely solid. These lines are termed liquidus and solidus, respectively. They are determined by taking cooling curves for a number of alloys in the series and plotting them as indicated by xy. The line ab represents an alloy containing about 60 per cent of B. On cooling to the liquidus, solidification commences, but the metal deposited is not of the same composition, being represented by n, mn being horizontal.

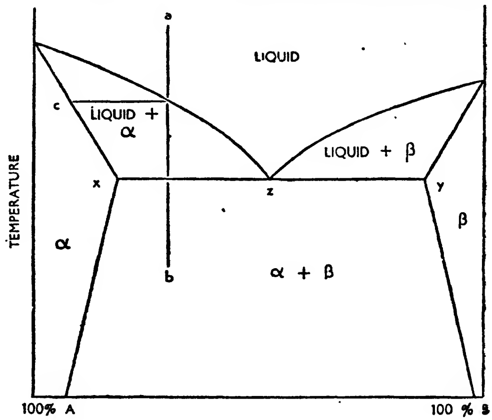


Fig. 2. Illustration is an example of a eutectic type of diagram. Very small amounts of x and y will continue to crystallize until solidification is complete, and alloy represented by x is a eutectic.

This reduces the amount of the metal B remaining in the liquid so that on further cooling it may, for example, be represented by the point O. This in turn will give rise to solid metal of composition p, and so on until the alloy is completely solid. The crystals will, therefore, consist of a dendritic core, rich in the metal B, each successive layer being less rich in this constituent. This effect is, to some extent, shown by micro-examination of cast solid solutions, but another action takes place during solidification to minimize this effect.

Liquid metal of composition o is in equilibrium with solid metal represented by p. But some solid metal of composition n is already deposited. Diffusion between the liquid and solid metal will, therefore, tend to occur to bring all the solid metal to composition p. Provided the rate of cooling is sufficiently slow this action will go on to completion, and no "coring" effect will be observed.

A typical diagram of the *eutectic* type is given in Fig. 2. Consider the alloy ab. On cooling the *a* solid solution of composition c will first be deposited. Solidification will proceed as indicated above until the residual liquid is of composition and temperature indicated by z. A horizontal line through this point will cut the solidus at x and also at y. There will, therefore, be an equal tendency for two different solid solutions, represented by x and y, to be deposited simultaneously. In actual fact a slight excess of the solid solution x will first crystallize, thus enriching the liquid with respect to B.

The tendency of y to deposit will then be too great to allow the first action to continue, and crystals of composition y will form until equilibrium is again upset. Minute amounts of x and y will, therefore, continue to crystallize until solidification is complete. The alloy represented by x is termed a eutectic, and in the solid state will consist of minute crystals, usually of lamellar form, of both the solid solutions x and y.

Fig. 3 is a typical diagram of the *peritectic* type. On cooling the alloy represented by ab, deposition of an *a* solid solution will occur until the residual liquid is of composition c. At this point, a reaction between the residual liquid and the *a* solid solution will occur, to produce a new

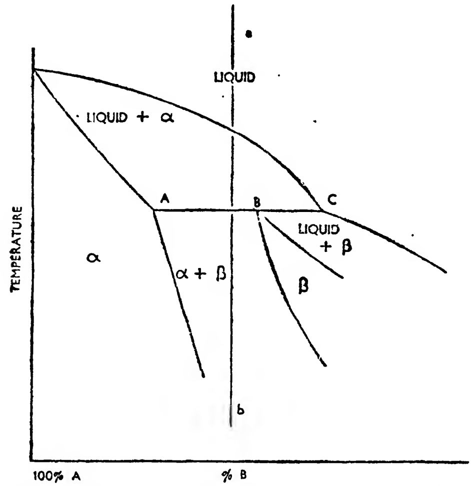


Fig. 3. Equilibrium diagram of the peritectic type. A reaction occurs to produce a new phase of composition B, but all the solid solution is not consumed in this reaction.

phase of composition B. As ab lies between A and B, all the α solid solution will not be consumed in this reaction.

The final structure will, therefore, contain crystals of both α and β phases. An alloy of composition between the limits B and C, will, however, consist entirely of the β phase. This process is termed a peritectic reaction. Such reactions rarely go to completion in actual practice. Typical diagrams of this type are given by copper-tin and copper-zinc alloys.

ERG. The centimetre-gramme-second unit of energy. It is the energy expended when a force of one dyne is exerted through a distance of one centimetre. One erg is equal to 10^{-7} joule.

ERICHSEN TEST, see CUPPING TEST.

ESPAVE, see MAHOGANY.

ESTER. An organic compound—that is, a compound of carbon—formed by the union of an acid and an alcohol with the elimination of water. Esters are usually volatile liquids soluble in alcohol or ether. Many of them have pleasant odours and occur in fruits. They are used as solvents, flavouring essences and perfumes.

ETCHING, see COLLOTYPE and ENGRAVING.

ETHANOL, see ALCOHOL.

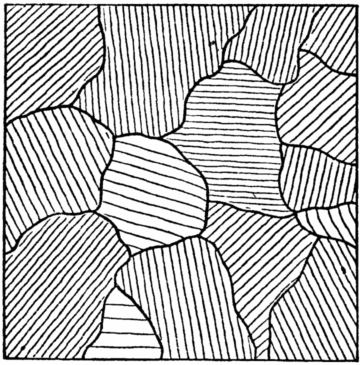
ETHYL ALCOHOL, see ALCOHOL.

ETHER. A term which has two distinct applications. In chemistry, the term refers to a colourless, very volatile liquid with a typical odour; density, 0·7135; b.p., 34·5 deg. C. Ordinary ether is diethyl ether, $CH_3.CH_2.O.CH_2.CH_3$; its vapour forms an explosive mixture with air. It is manufactured from alcohol by treatment with sulphuric acid, and is used as a solvent in the chemical industry and as an anæsthetic.

In radio, the term denotes the medium through which electric and electromagnetic waves are said to travel. See RADIO-WAVE PROPAGATION.

EUCALYPTUS. A valuable Australian genus of tree, of which there are over 300 species, varying from the largest known hardwoods to mere shrubs; many of them are of no value for timber, but the commercial woods are highly esteemed for many purposes in carpentry and joinery. They are hard, heavy, durable, tough, strong and fire-resisting. The best known are jarrah, karri, gums, box, mountain ash, blackbutt, coolibah, gimlet, messmate, peppermint, red mahogany, stringybark, tallow wood, Tasmanian oak and yate. See TIMBER.

EUTECTIC. A mixture, of two or more metals, that melts or solidifies completely at a fixed temperature lower than that of any other alloy of the constituent metals. In the solid state the structure is duplex in binary alloys, consisting of finely intermixed crystals of two different substances which may be pure metals, solid solutions, or metallic compounds. The structure may be lamellar or finely granular, depending on the particular alloy and



Above is a diagrammatic representation of the microstructure of a eutectic. Note the variation in the width of the lamellae, and also the varying orientation in the different grains.

the rate of cooling from the liquid state.

EUTECTOID. A structure, similar to a eutectic (q.v.), formed in the solid state in cooling a single phase—usually a solid solution. Probably the best-known example occurs in the iron-carbon system. Iron containing 0·87 per cent carbon consists of a solid solution of carbon in iron, known as austenite (q.v.), at temperatures above 700 deg. C. On cooling through this temperature, the austenite decomposes into ferrite (q.v.) (pure iron) and cementite (q.v.) (iron carbide) to form a lamellar eutectoid known as pearlite (q.v.). Iron-carbon alloys containing more or less than the eutectoid proportion of carbon first deposit cementite or ferrite as indicated by the lines OS and GO in the diagram until the residual is of the eutectoid composition. See EQUILIBRIUM DIAGRAM (EUTECTIC).

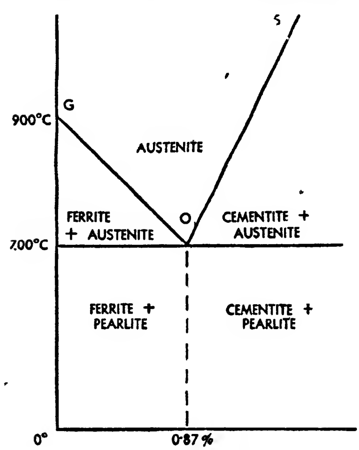


Diagram of a eutectoid. The example shown above is probably the best known and occurs in the iron-carbon system.

EVAPORATIVE COOLING, see COOLING.

EXCITATION. The use of an electric current to produce a magnetic field in an electrical generator or other apparatus. The term is also used to refer to the actual current or the magnetomotive force produced thereby. It is then generally expressed in amperes or ampere-turns, respectively. See AMPERE-TURN.

EXCITER. An auxiliary electrical generator used to provide the excitation of another machine. It may be separately driven, but it is often mounted in line with the machine it supplies.

EXHAUST SILENCER. A chamber into which the exhaust gases of an internal-combustion engine pass and where they expand before escaping into the atmosphere. It contains a number of baffle plates which restrict the direct flow of gases so that their explosive force is expended before they are expelled.

EXHAUST STROKE. The half revolution of the crankshaft of a four-stroke internal-combustion engine when the piston is sweeping the burnt gases through the open exhaust valve into the exhaust system (q.v.).

EXHAUST SYSTEM. Any system for getting rid of wasted steam, or of gases in internal-combustion engines. On road vehicles the exhaust gases are forced out of the cylinder on the exhaust stroke (q.v.) through the open exhaust valve, into a pipe which, in most cases, is common to all the cylinders and is known as the exhaust manifold.

The manifold is secured to the

cylinder block by a flange at each cylinder outlet; a gasket (q.v.), fitted between the flange and cylinder block, ensures a gas-tight joint. From the manifold the gases pass through an exhaust pipe to the silencer and from there, through a short length of pipe, into the atmosphere. All the joints between cylinder outlet and silencer should be maintained in a sound condition or exhaust gases may find their way into the vehicle with unpleasant results.

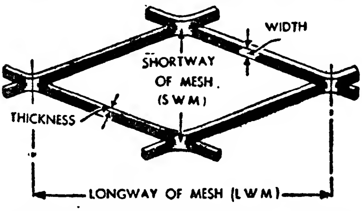
EXHAUST VALVE. The valve which, during the exhaust stroke (q.v.) of an internal-combustion engine, permits the flow of exhaust gases from the cylinder. See EXHAUST SYSTEM.

EXIT TENSION. A means of effecting and controlling thickness reduction in the cold-rolling of sheet metal. As a coil of metal passes through the rolls it may be re-coiled on the exit side on a power-driven reel, and the tension imposed by the latter unit has a known and controllable effect in the reduction achieved. See SCREWDOWN.

EXOTHERMIC. A term used to denote (1) a chemical reaction in which heat is evolved, and (2) a chemical compound formed from its elements with the evolution of heat.

EXPANDED METAL. A term applied to a wide variety of lattice- and diamond-shaped mesh structures. Each structure is made from rolled sheet, the material being cut and expanded to shape without waste. Thus the strength of the product does not depend upon any attachment process, as the strands are all part of one piece.

British Standard Specification for Expanded Metal (Steel) No. 405–1930 covers the physical properties of steel sheets for this purpose. Ductile metals other than mild-steel can be expanded, e.g. aluminium, brass, copper and stainless steel. The illustration gives the usual descriptive nomenclature associated with this material.



Product of the Expanded Metal Co., Ltd., showing how the terms are used.

EXPONENTIAL HORN. A loud-speaker horn or trumpet whose cross-sectional area increases with respect to its length according to a logarithmic law.

EXTRA-HIGH VOLTAGE. An electrical term used to describe the highest voltages at present in use. It may be regarded roughly as indicating voltages above 100 kilovolts.

EXTRUSION OF METALS. A process in which pressure is applied to the solid billet causing the metal to flow through a relatively small orifice to produce a length of solid bar or hollow tube of smaller cross-section than the original billet.

The process may be carried out hot or cold on mechanical or hydraulic presses, the total applied pressure sometimes being greater than 5000 tons; hydraulic presses are used for the higher pressures. The extrusion of lead, tin, zinc, lead-tin alloys, pewter or Britannia metal is usually carried out at normal temperatures, while tin-base alloys, magnesium-base alloys, copper and alumina and their alloys are extruded hot.

The pressures for soft lead range from 18 to 27 tons per sq. in.; for antimony and tin-bearing alloys they are 50 per cent higher. The speed of extrusion is as much as 200 ft. per min. in the case of soft alloys and 20 to 80 ft. per min. for harder alloys. Lead pipe is extruded from a vertical press, the metal being supplied in a molten state, but solidifying before extrusion.

Copper alloys are extruded hot (675 to 815 deg. C.) at pressures of up to 3,500 tons and speeds of 20 to 500 ft. per min. Tube-extrusion presses work at from 1100 to 4500 tons pressure at speeds up to 1000 ft. per min.

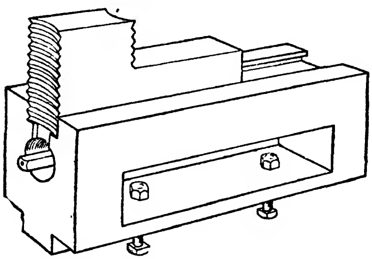
Aluminium and all the high-strength alloys may be extruded,

aluminium being the easiest and the high-strength heat-treatable alloys the most difficult. These alloys are extruded hot (370 to 510 deg. C.) at speeds of from 5 to 300 ft. per min. The capacity of the press may be as high as 5000 tons.

Magnesium-base alloys are extruded hot (315 to 430 deg. C.) at pressures of 18 to 27 tons per sq. in., and speeds of 2 to 12 ft. per min. Since these alloys are brittle at ordinary hot-working temperatures as compared with other materials, only a narrow temperature range can be used. High-grade zinc is extruded at speeds up to 75 ft. per min., and zinc alloys up to 12 ft. per min., the pressure amounting in the case of the latter to as much as 50 tons per sq. in.

FABRIC JOINT. Disk of woven material inserted, in engineering practice, between the ends of two shafts as a coupling to give flexibility. The shafts are fitted with three-pronged spiders, bolted to opposite faces of the disk in such a way that the prongs on one face come midway between those on the other. The fabric is rubberized and the holes are reinforced by metal plates to give greater durability. Little maintenance is required by this type of joint apart from keeping the bolts tight and preventing excessive wobble of the shafts.

FACEPLATE. Usually the disk attached to the driving spindle of a lathe and to which the workpiece is fastened, but the term is also applied to cover-plates and facing-pieces used for protective purposes. Lathe faceplates are usually provided with four, six, eight or more slotted grooves, arranged radially, into which T-headed bolts can be inserted.



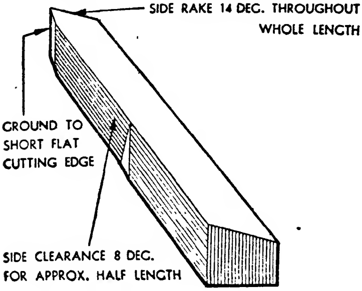
Above is shown an attachment for a faceplate. It may be used either for holding the actual article on the faceplate or for holding the special jaws, three or four of which may be used.

The bolts are used for tightening slotted clamps as shown in the illustration, which bear at one end on the workpiece and at the other end upon suitable packing, so that both faceplate and workpiece rotate as one. Sometimes special jaws, which can be attached to lathe faceplates, are used on vertical boring mills to fasten work to the table. Usually three or four of them are bolted by square-headed bolts to slots of T-section in the faceplate, and are adjusted so as to grip the workpiece by screwing the movable portion inwards or outwards.

FACING. The operation of machining the ends of a workpiece so that they have truly flat surfaces square to their longitudinal axis. The workpiece will either be mounted on a faceplate or held in a chuck; the latter is preferable, wherever possible, as the work is not rotated between centres; therefore, as no centring is needed before facing, a clean facing job can be carried out. The drawback of using a chuck is that the workpiece cannot be allowed to project more than 3 or 4 in. if accurate work is required.

When facing between centres, remember that the pressure of the cutting tool during roughing cuts tends to enlarge the "centre" at the tailstock end, and thus to produce a burr around it; the final facing operation, therefore, is best carried out after all the roughing cuts have been taken. A side tool is normally used for this work.

A variety of patented holders are available, but the ordinary tool holder, with a tool ground as illustrated, is



Tool for facing is illustrated above. It will be noted that the tool should be set, to obtain a good finish, so that the tip of the tool contacts the work before the rest of the cutting edge.

generally as serviceable. The tool should be ground either with an extremely small radius at its tip, or to present a short flat surface to the workpiece. This will promote a smooth finish. Not all the actual cutting edge should be in contact with the work i.e. at right-angles to the centre line; the tool should be at a slight angle so that the tip points somewhat towards the headstock.

FADING (Painting). All coloured paints upon external surfaces are liable to lose a little of their colour strength owing to the gradual granulation of the surface through mechanical damage by the weather. Lakes and pigments formed by fixing a dye upon a white base are particularly liable to fade if subjected to strong sunlight, therefore their use in such situations should be avoided.

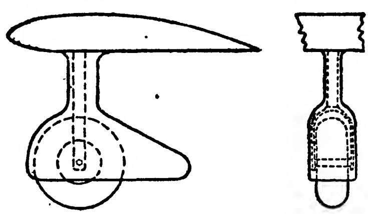
FADING (Radio Engineering). Variations in the strength, and sometimes in the quality of radio signals brought about by changes in the condition of the ionized layers in the upper atmosphere. *Selective* fading gives rise to peculiar tonal distortion of telephony signals owing to some of the frequency components of a transmission being affected differently from others. No system such as automatic gain control (q.v.) is able to overcome this. See RADIO-WAVE PROPAGATION.

FAGGOTTING, see BALING.

FAHRENHEIT SCALE. A thermometer scale in which the freezing-point of water is 32 deg. F., and the boiling-point, 212 deg. F. The equivalent centigrade degree is found from the formula $C=5(F-32)/9$.

FAIENCE. A burnt-clay product made from fairly plastic clays. The same definition applies to terra-cotta, but the exposed surfaces of faience are glazed or enamelled in various colours. It is manufactured in the form of hollow blocks and is used as a medium for facing the skeletons of buildings and to produce an architectural effect.

FAIRING. A cover of streamline shape placed over a bluff external part of a vehicle to minimize drag. The



Above is an example of fairing for the undercarriage of an aircraft. Note how the streamline is shaped in order that the drag caused by the undercarriage shall be reduced to a minimum.

illustration shows the undercarriage fairing of an aircraft.

FALL. The slope of a drain-pipe, roof or paving, for the purpose of getting rid of waste, surface water or sewage. The minimum fall of a drain should be such as to prevent solids being left in the pipe. The maximum will be governed by local conditions, such as the depth of the sewer and site circumstances.

A flow velocity of from 3 to 4 ft. per sec., however, is usually considered sufficient when the depth of water is $\frac{1}{3}$ the diameter of the pipe. As the fall necessary to obtain this velocity varies directly as the diameter of the pipe, the rule generally adopted is to multiply the diameter of the pipe in inches by 10, and to regard the result as the length in feet which should have a fall of 1 ft. The velocity

of flow will then equal approximately $4\frac{1}{2}$ ft. per second.

The following table gives some comparative falls for different diameters:

4-in. drain—$4 \times 10 = 40$ feet run for 1 foot fall = 1 in 40.

6-in. drain—$6 \times 10 = 60$ feet run for 1 foot fall = 1 in 60.

9-in. drain—$9 \times 10 = 90$ feet run for 1 foot fall = 1 in 90.

FAN. A device used in many branches of engineering to increase or create a draught. One of the most common uses of a fan is on the engine of a motor vehicle where, situated immediately behind the radiator, it is belt-driven at high speed from the crankshaft. Its purpose is to increase the efficiency of the cooling system by accelerating the flow of air through the radiator tubes. See COOLING.

FARAD. Symbol: F. The practical unit of electrical capacitance. A condenser has a capacitance of one farad if one coulomb of electricity raises its potential difference by one volt. This unit is so large that for most purposes, the microfarad is more convenient. A microfarad, sometimes abbreviated as μF, is one millionth part of a farad. See CAPACITANCE and CONDENSER.

FARADAY'S LAWS, see ELECTROLYSIS and ELECTROMAGNETISM.

FASCIA. A band or fillet. The term *fascia course* is applied to the plain course of facing material placed over a large opening. Although the material comprising such a course may be jointed to give the appearance of solid stones, it is usually a veneer, or covering, to the structural member which supports the weight of the walling material over the opening. The stones are attached or connected to the structural member by some form of connecting device.

FASCIA COURSE, see FASCIA.

FATS. Compounds of glycerine and fatty acids. Glycerine, otherwise glycerol, is a compound of the formula $CH_2OH.CHOH.CH_2OH$. Three hydrogens can each be replaced by a part of a fatty acid, and there are many such acids, of which oleic acid, palmitic acid, and stearic acid are the most generally known. The term "fat" is commonly used to denote compounds that are solid at ordinary temperatures.

The three hydrogens may be replaced by parts of the same fatty acid, but usually they are replaced by parts of three different fatty acids. As there are many different fatty acids, the number of different fats is very large. Fats are not soluble in water, but are usually soluble in hot alcohol and other organic solvents. See GLYCERINE.

FEATHER KEY. A light, simple means of fastening a hub to a shaft without the necessity of machining a tapered surface, such as is used for keys which are a driving-fit. The parallel portion of a feather key is usually of square cross-section, the ends being shaped to suit the machined hub into which they are dropped before hub and key are together slid into position on the shaft as shown in Fig. 1.

Set screws are often used to keep feather keys from working out; in some cases the set screws bite directly on the feather key, whilst in others, illustrated in Fig. 2, they are used to

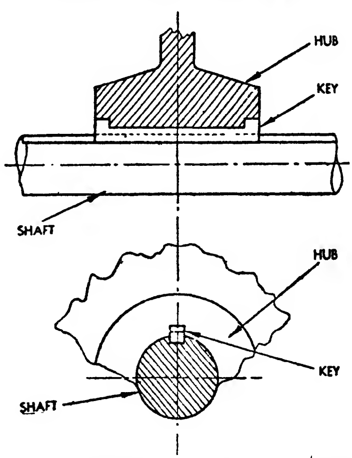


Fig. 1. Side and end views of a shaft, showing the feather key by means of which a hub is secured to the shaft so that they will rotate together. The hub is specially machined to take the key, which is fitted into place before being slid on to the shaft.

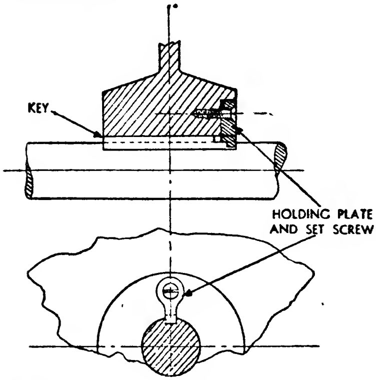


Fig. 2. Section through another type of feather key in which, in order to ensure that it remains in position, a holding plate and set screw are used and endwise movement is prevented.

secure a holding plate on to the hub, the plate covering the end of the key and preventing endwise movement.

FEED-BACK. The transference of energy from the output of an electric amplifier to its input circuit. See ACOUSTIC FEED-BACK and NEGATIVE FEED-BACK.

FEEDER. An untapped electric cable or overhead line connecting a distributor with a supply point such as a sub-station. The term also applies to a line or cable supplying the live conductors of a traction system. See DISTRIBUTOR and TRANSMISSION LINE.

FEEDING-UP, see CURDLING OF PAINT.

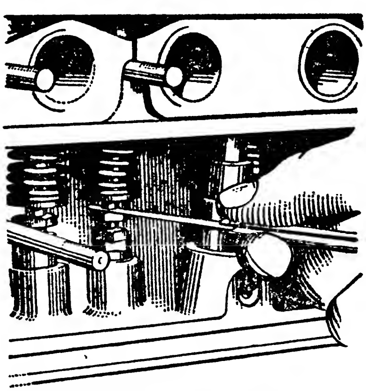
FEELER GAUGE. A thin piece of steel used for measuring the distance between two components when they are required to be set a short distance apart. It is usual to have a number of gauges of different thicknesses fastened together in the form of one tool, and measurements from 0·001 in. upwards can be made by inserting the blade between the two faces, as between tappet and valve stem when setting the poppet valves of an internal-combustion engine. See VALVES AND VALVE GEAR.

FELTING PAPERS, see ABRASIVES.

FELSPARS. Anhydrous silicates common in many volcanic rocks, and sandstones derived from volcanic rocks. One of the commonest is orthoclase, $K(Si_3Al)O_8$, which is used in making pottery and, when finely ground, has been used as a fertilizer. Albite has the composition $Na(Si_3Al)O_8$. Labradorite is a sodium-calcium felspar; rocks of this often show beautiful colours and are used in building as ornamental stones.

FENDER WALL. The dwarf wall which supports the front of the concrete hearth to a fireplace-opening at ground-floor level. The wall is built-up from the surface concrete in front of the chimney jamb. Its other function is to receive the wall-plate for the support of the ends of the floor joists, which are situated immediately in front of the chimney breast. The omission of the fender wall would necessitate trimming the floor joists as for an upper floor.

FERRITE. Alpha iron, a very soft and ductile material, present in



Feeler gauge is here being used to ascertain the clearance between tappet and valve stem of a poppet valve on an internal-combustion engine. Feelers may be used in conjunction with other gauges in engineering shops to ascertain the dimensions of certain components.

annealed steels containing less than 0·87 per cent carbon, and in soft cast-iron. It can dissolve 0·01 per cent carbon at room temperature increasing to 0·03 per cent at 700 deg. C. This minute amount of carbon has important age-hardening effects on low-carbon steels. In addition to

carbon, ferrite may dissolve considerable quantities of silicon, chromium, manganese, nickel and tungsten. The mechanical properties of pure ferrite are: ultimate stress, 22 tons per sq. in. and elongation, 40 per cent.

FERRO-ALLOY. An alloy of iron containing a considerable proportion of another element, or elements, such as chromium, manganese, silicon etc. Such alloys are used for adding definite quantities of a required element to cast-iron, steel etc. For example, ferro-manganese is added to steel to introduce both carbon and manganese. Ferro-alloys, unlike ferrous alloys, need not consist mainly of iron. Thus ferro-silicon is obtainable in a number of different grades containing 10, 50, 75 per cent of silicon etc. See FERROUS ALLOY.

FERROMAGNETIC. The magnetic quality of a substance possessing a high permeability, which varies with the magnetizing force to which it is subjected. Iron is a ferromagnetic substance. See PERMEABILITY.

FERROUS ALLOY. An alloy consisting mainly of iron. Cast-irons and steels, to which proportions of alloying elements such as nickel, chromium, or molybdenum etc., have been added with a view to modifying or improving chemical, physical or mechanical properties, are excluded from the definition. They are instead described as alloy cast-irons or alloy steels respectively.

FERTILIZERS. Compounds or admixtures added to the soil chiefly for their nitrogen, phosphorus or potassium content. The most widely used nitrogenous fertilizer is ammonium sulphate. The most important fertilizers containing phosphorus are the superphosphates, which are tricalcium phosphates treated with sulphuric acid to increase their solubility. Mixed fertilizers may contain all three elements.

FIBROUS PLASTER. A combination of plaster of Paris, canvas or scrim, and laths, united into a structural mass in the form of precast slabs and lengths of mouldings. It is used for the covering of timber stud partitions, beam coverings, suspended ceilings, cornices and interior decorative treatment of all kinds. It is usually secured to timber framing and firring pieces with galvanized nails, but galvanized wire is sometimes cast in the plaster units and used as a means of attachment. Metal lathing and rods are often used to support fibrous-plaster slabs, cornices, coverings etc. The necessity of housing and covering service pipes, conduits and ventilation ducts has led to the more general use of fibrous plaster.

FIELD-DISCHARGE SWITCH. An electrical switch arranged to open the field circuit of an electrical machine and at the same time to connect a resistor in parallel with the field. The purpose of the resistor is to absorb the energy stored in the magnetic field produced by the field winding.

FIELD REGULATOR. A resistor used to vary the field current of an electrical machine. It is connected in series with the field windings. A resistor connected in parallel is known as a diverter (q.v.). Synonym: Field Rheostat.

FIELD RHEOSTAT, see FIELD REGULATOR.

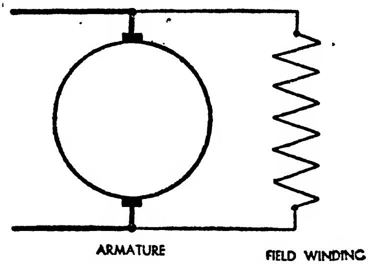
FIELD STRENGTH. The strength of a radio signal at any given point. It is usually expressed in microvolts induced in an aerial having an effective height of one metre.

FIELD SYSTEM. The stationary part of an electrical machine of the rotating-armature type. It comprises the yoke, poles and the field windings. The term is sometimes used to mean the flux-producing portion of an electromagnetic device.

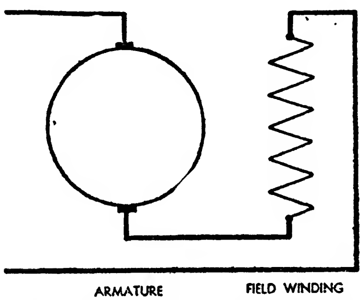
FIELD WINDING. A winding, which is used for flux production, in an electrical machine. Such a winding may be shunt or series connected, as shown in the diagram opposite, but compound-wound machines have both types of field winding. See COMPOUND WINDING.

FILAMENT, see CATHODE and DIRECTLY HEATED VALVE.

FILE. An abrading tool made in a very great number of shapes and sizes,

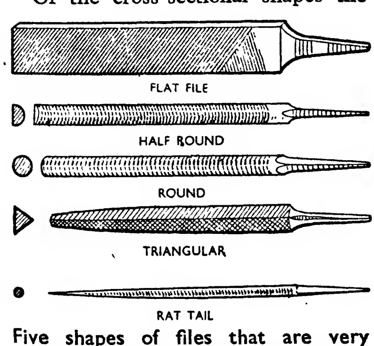


Shunt field winding (shown at top) normally carries a small current and is wound with many turns of comparatively fine wire, whereas a series winding (shown in the diagram below) consists of a few turns of heavy conductor because it has to carry all the current.



many of which are for specialized jobs and have very limited application. Files, some of which are shown in the illustration, may be classified, first, according to their cross-section and second, according to the spacing of the teeth.

Of the cross-sectional shapes the



Five shapes of files that are very often used. Note that the length of a file does not include the tang.

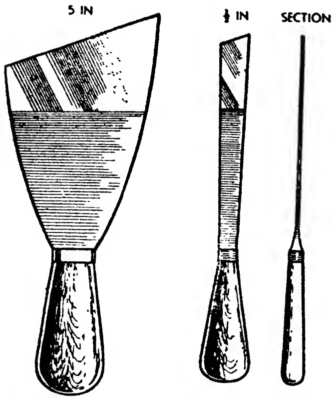
principal varieties are: flat (thin rectangular), half-round, round, square, three-square (triangular) and knife (thicker at one edge than at the other). Files are either single-cut or double-cut. In the former, sometimes known as saw-files, there are parallel rows of teeth across the face, the angle of the rows to the edge being 65 to 85 deg. Double-cut files have two series of teeth, the parallel rows of each series intersecting at a uniform angle; the first rows make an angle of 40 to 45 deg. with the axis of the file, while the angle of the second row is about 70 to 80 deg.

Both single-cut and double-cut files are still further graded according to the number of cuts per inch, which may vary from 14 to 100 or more. The grades, from coarsest to finest, are known as: rough, coarse, bastard, second-cut, smooth and dead-smooth. Generally, all rough files are of the single-cut type; all dead-smooth files are double-cut, the intervening grades being made in both varieties. In describing the length of a file, the tang, or tapered end for fitting into a handle, is not included.

FILLERS (Painting). Materials used for correcting the general unevenness of a surface before painting or polishing. For painting, fillers are usually supplied in paste form and are inert materials—slate, china clay etc. —ground in a drying oil medium, and diluted with turpentine or white spirit for application by brushing. They are freely applied and, when dry, are cut down to an even plane surface by the abrasive action of a pumice-stone block lubricated with water.

Fillers made on the job are: distemper fillers, dental or statuary plaster and whiting in even quantities, mixed dry and worked into a paste by the addition of weak jellied size; or the paste white supplied for use as a washable distemper and stiffened by the addition of whiting.

Oil-fillers; white-lead paste ground in linseed oil and dry whiting in even quantities, worked into a paste by the addition of japanners' gold size and reduced to a working consistency with



FILLING KNIVES

Filler knives are an essential part of the equipment of the painter and decorator as, in many cases, cracks and bad joints will require attention.

turpentine or white spirit; or, for quick work, dry white lead and dry whiting, in even quantities, worked into a paste with japanners' gold size and reduced to a working consistency with turpentine or white spirit.

Note:—This is the only job for which a painter can purchase dry white lead. Regulations do not allow builders or painting contractors to buy or stock white lead in a dry form; it must be purchased as required by the person who is going to use it. All the above are applied, upon a priming coat of paint, with knives, as illustrated, made specially for the purpose and varying in width from ½ to 5 in.

FILLET. A strip of wood, cement or other material fitted into an angle between surfaces in different planes or as a covering strip over butting materials in the same plane. The term is used in connexion with aircraft to denote a cover placed over the junction of two parts of the main structure to reduce interference drag.

FILTER (Auto. Engineering). A device for cleansing liquids or air. A common type of filter for lubricating or fuel-feed systems, fitted to most road-vehicle engines, is made of very fine wire gauze, but this does not catch minute particles of grit. A more efficient type is one employing a number of fabric rings, or packs. Filters should be examined frequently and any dirt that has accumulated should be removed. See OIL CLEANER.

FILTER (Radio). An electrical network so designed that the ratio of its output current to its input current is as near unity as possible over a certain range of frequencies, and extremely low at other frequencies. The circuit elements are termed *network constants* or *parameters* and comprise a combination of resistances, capacitances and inductances (self and mutual) connected together in some predetermined manner.

Filters are of many types according to the function they have to fulfil. There are, for example, *low-pass* filters which, as the name implies, pass the lower-frequency currents and severely attenuate those of higher frequency. On the other hand, there are *high-pass* filters, and it will be clear that they attenuate low-frequency currents and pass those of high frequency.

It is sometimes necessary to pass only a specified band of frequencies, attenuating all signals above and below this band. For this purpose a *band-pass* filter is employed. Again, it may be desirable severely to attenuate a band of frequencies, e.g. "hiss" on gramophone records, when a *band-stop* network would meet the requirements. In certain circumstances, a filter may be designed and used simply to suppress one particular frequency or to allow just a single frequency to pass. An important application of a simple type of filter in mains-operated radio receivers is in the suppression of the "hum" or ripple content in the H.T. supply system. See SMOOTHING.

FINISH COAT, see COVER COAT.

FINISHING (Bookbinding), see BOOKBINDING.

FINISHING TRAIN. A series of four-high mill stands used in the production of sheet metal, situated after the roughing train (q.v.), to reduce rolled metal to hot-finished thickness. Practice varies in different

works according to the weight of coils required; four, five and six stands are used. An attempt has been made on the Continent to interpose a heated coiler between each stand in order to equalize the metal temperature during rolling, but the method has not found ready acceptance in the industry.

FIR (Carpentry). A softwood found in N. Europe and Canada, showing considerable variations in quality. The best qualities of spruce, such as Sitka, are used for good-class work because of their toughness, strength and clean, white appearance. Baltic whitewood, fir, or white deal, is used for cheaper constructional work, and the best qualities for flooring and inferior joinery. See TIMBER.

FIRE-RESISTANCE OF WOOD. Although inflammable when fed with air, timber in bulk is very resistant to fire as the surface chars and provides a natural barrier against combustion. Solid construction is recognized as fire-resisting, and is commonly applied to floors, doors, stairs etc.

Many timbers, however, are naturally resistant to fire and the London County Council has issued a list of those recognised as fire-resisting. This includes English ash, crabwood, Douglas fir, karri, jarrah, iroko, keruing, meranti, Nigerian walnut, mora, oak, padauk, pyinkado, Secondi mahogany, silver greywood, Tasmanian myrtle and teak. The list is extended periodically, as experience and investigation prove the resistance of the wood.

Improved resistance can be obtained by surface coatings, and there are several proprietary paints on the market which are very effective and easily applied. Like all paints, however, they require periodic renewal. The most effective treatment is chemical impregnation under pressure. All air and moisture are first extracted from the wood; the chemicals are then forced into the pores, where they crystallize.

The object is to exclude air in the event of fire, and this can be done in two ways: the crystals either generate non-inflammable gases under heat, or they fuse and seal the cells. Chemicals in general use include alum, borax, calcium chloride, ammonium chloride, ammonium sulphate and ammonium phosphate.

FIRE-RESISTING CONSTRUCTION. A term applied to buildings in which fire-resisting materials are used and which have floors and roofs constructed in reinforced concrete, or steel and concrete, and hollow blocks. The ability of a building to withstand the effects of fire may be defined in terms of the time it would take for the structural members, including walls, floors, stairways, and roof to become unsafe, or damaged to such an extent that they would be unable to fulfil the function for which they were intended.

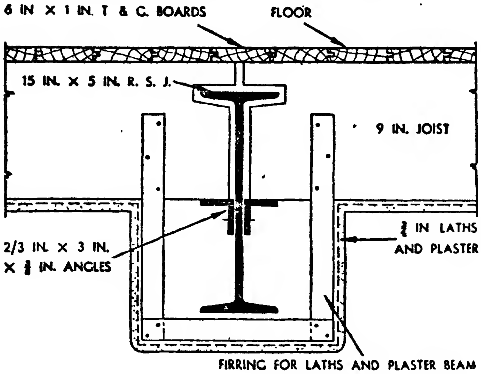
FIRE-TUBE BOILER, see BOILER.

FIRING ORDER. The order in which the cylinders of a multi-cylinder internal-combustion engine are timed to produce combustion. On four-cylinder engines the sequence is either 1, 3, 4, 2 or 1, 2, 4, 3 while a six-cylinder engine would fire 1, 5, 3, 6, 2, 4 or 1, 4, 2, 6, 3, 5. The cylinder nearest the radiator is usually known as No. 1. The correct firing order can be determined by observing the sequence of the valve operation.

Assuming that it is required to find out the order of a four-cylinder engine, remove the valve cover and turn the crankshaft slowly in the direction of rotation until the inlet valve of No. 1 cylinder is opening. As the crankshaft is turned further, watch for the opening of the next inlet valve. If this is on 3 cylinder the next in order would be No. 4 and, finally, the last inlet valve to open would be No. 2, establishing a firing order of 1, 3, 4, 2. See FIRING STROKE.

FIRING STROKE. The half revolution of the crankshaft of a four-stroke internal-combustion engine when the explosive charge has been ignited in the combustion chamber. Both valves being closed, the piston is forced down the cylinder bore, thus producing the power required to rotate the crankshaft.

FIRRING. Any framework of wood or metal which is not part of the



In the above, firring is used for a suspended ceiling. It is fixed to the joists, and it is to this that the laths and plaster are attached.

structure of a building, but is used to build up surfaces to assist the requirements of interior architectural design.

Wood firring consists of a light framing, built up so as to assist in covering floor beams, and in the construction of covings, cornices and suspended ceilings. Firring pieces are also used in the construction of flat timber roofs to obtain the fall for the roof surface, in which case, tapered pieces of timber are nailed on the top surfaces of the timber joists in the same direction as the joists. See FLOOR BEAM.

FIVE-ELECTRODE VALVE, see PENTODE and RADIO VALVE.

FIXERS, see MASONRY.

FIXING BRICK. A brick made from coke breeze or synthetic material which will permit nails being driven into it. Fixing bricks are built into and form part of the wall. Their function is to assist in securing door and window frames, skirtings, picture rails and other items of joinery work.

FIXTURES, see JIG.

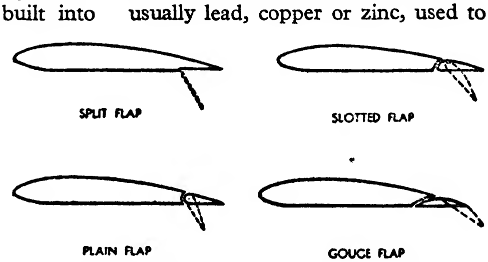
FLAKE WHITE, see WHITE LEAD.

FLAKING (Painting). The fracturing, and detachment from its base, of an applied film caused by placing a hard-drying material upon unstable foundations. The chief cause of this defect is the application of washable distemper or water paint upon surfaces which have been prepared with glue size or have been previously treated with glue-bound distemper and only indifferently washed-off. The direct application of a flat oil finish upon old oil paint without first washing clean and granulating the surface, also causes this defect.

FLAP. A hinged portion of the trailing edge of an aeroplane wing, which can be deflected to increase the maximum lift coefficient (q.v.), and thus decrease the stalling speed. The flaps on a monoplane usually extend from fuselage sides out to the inboard ends of the ailerons. Flaps may be of several forms; the illustration shows some of the most common types in both up and full-down positions. An intermediate position giving some lift increase without much drag increase is often used for take-off.

FLAP VALVE. An air valve having a mica flap which allows air to pass in but not out, usually employed in ventilating a drainage system. Fresh air can blow into and through the drain by pushing the flap inward, but foul air, on rising, merely closes the flap and thus seals the exit.

FLASHING. A strip of metal, usually lead, copper or zinc, used to



Four designs of flap in common use, showing both the up and full-down positions. Intermediate positions are used at take-off to increase lift.

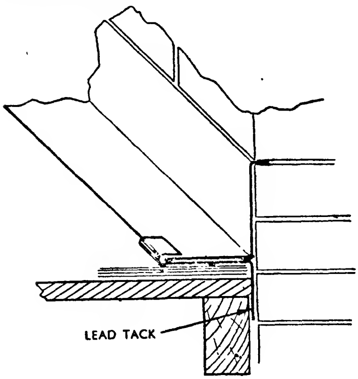


Fig. 1. Flashing with its top edge turned into the brickwork. A lead tack securing the flashing is shown.

cover a joint between a sloping roof and a wall, and make it weather-tight. The top edge of the metal strip is turned into the brickwork for about 1½in. while the main width hangs down over the upstand of the gutter or soaker (q.v.). In Fig. 1 is shown a step-and-cover flashing that is wide enough to lie flat upon the roof, and turn up and into the wall. Flashing strips are secured in walls by means of wedges, and the joints are pointed with mastic or cement mortar (see STEPPED FLASHING).

When a flat roof surface is to be covered with asphalt, a soaker is not always necessary, as the asphalt sheets can be turned up the adjoining vertical brickwork for about 5 in. so that a hanging cover flashing is sufficient. An arrangement of this kind is shown in Fig. 2.

FLASH-OVER. An arc between adjacent parts of an electrical machine or apparatus, which occurs unintentionally, or is produced purposely for test purposes. An example of the first kind is a flash-over round the commutator of a D.C. shunt-motor caused by a sudden interruption of the field current. The second kind is typified by a flash-over test on an insulator made to determine the voltage which will cause it.

FLASH POINT. The temperature at which a liquid, heated under standard conditions, gives off enough vapour to ignite on the application of a small flame.

FLASK. In foundry work, a moulding box usually consisting of wood, cast-iron or pressed steel. It is used for holding the sand mould in which a casting, possibly in several sections, is made. The term is in more frequent use in America than in Britain. See COPE and DRAG.

FLAT JOINTS, see POINTING.

FLATTING (Painting). A straight oil paint which dries with a dull finish. It is made from white-lead paste or zinc oxide ground in linseed oil, broken-up in a little varnish and diluted with turpentine or white spirit.

For pale colours, the white paste may be tinted with pigments ground

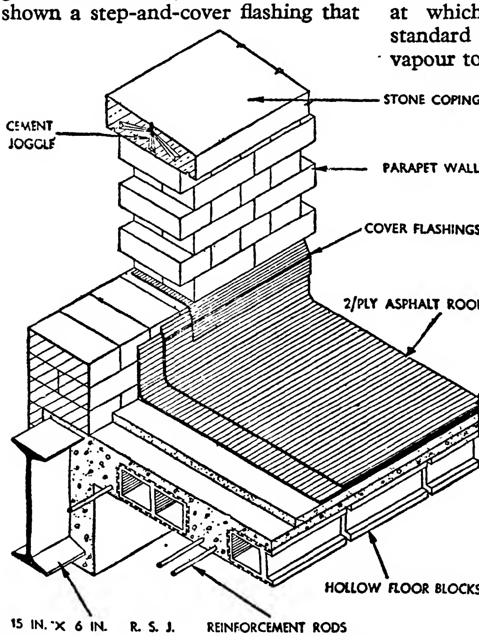


Fig. 2. Arranging an asphalt covering without a soaker for use on a flat roof surface.

in linseed oil. Dark, rich colours can be satisfactorily made only by having the coloured pigments ground in turpentine; they are broken up in japanners' gold size and diluted to a working consistency with turpentine or white spirit.

Flatting is applied evenly and regularly in a good flowing coat, upon an oily undercoating of about the same colour; it is then stippled while still wet with the ends of the bristles of a large, flat soft-haired brush known as a stippler. The flatting should be applied within 24 hours of the undercoating.

FLATTING VARNISH. A quick-drying varnish which dries with a glossy finish sufficiently hard after the lapse of 24 hours for cutting-down with an abrasive. It is an undercoating varnish and is not intended for a final finish.

F-LAYER. One of the electrified layers in the ionosphere (q.v.). See RADIO-WAVE PROPAGATION.

FLEMING VALVE. A two-electrode valve, or diode, produced by Fleming in 1904. Used for the reception of radio signals. See RADIO VALVE.

FLOAT (Aero. Engineering). Those parts of a seaplane which are sometimes known as *pontoons*, and which provide its buoyancy. They are usually divided into several watertight compartments and have planing bottoms similar to that of the hull of a flying boat. Small floats are often placed underneath the wing tips of flying-boats to provide lateral stability on the water. They are then known as wing-tip floats. The term is also used to denote that part of the landing manœuvre of an aircraft between flattening-out and touching down.

FLOAT (Building). A tool used by plasterers for rubbing over a screeded surface to form an even finish over all irregularities. It is similar in shape and size to the plasterer's laying trowel, but is generally made of wood.

FLOAT CHAMBER, see CARBURETTOR.

FLONG. A sheet of soft card or papier-mâché used for making a mould for a letterpress printing plate or forme. The flong is damped and pressed on the raised type-face, the result being a mould in reverse. Where a large number of copies is required a flat stereo is made from this mould for use on platen machines.

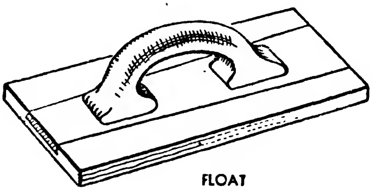
For the rotary press, however, the mould is bent to a semi-circle and placed in a cylindrical container known as an autoplate machine, the moulded side being placed inwards. Molten metal is then poured into the annular space between the mould and the core, and the stereo is thus cast.

In newspaper work the stereo may form one or more complete pages of type and occupies one-half the circumference of the roller of the rotary press on which it is afterwards bolted. See ELECTROTYPE and STEREOTYPE.

FLOOR BEAM. A beam introduced in the construction of a floor, when the distance from wall to wall is more than 16 ft., in order to divide the floor area into smaller bays and to support the ends of the floor joists. Timber beams termed *binders* were at one time commonly used for this purpose, but in modern floor construction, rolled-steel joists are preferred.

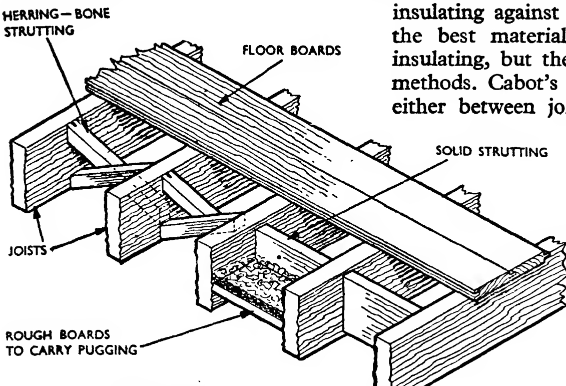
In this case, the ends of the timber joists are trimmed to fit into the contour of the steelwork, or the joists may rest upon the top flange of the steelwork. The projecting lower portion of the beam is usually firred-out and covered with plaster, to produce the appearance of a rectangular beam supporting the floor above. See FIRRING.

FLOORING. Timber used as floor-boards. Many different woods are



FLOAT

Floats are used to obtain even finishes. Although similar to plasterers' laying trowels, they are usually of wood.



FLOOR STRUTTING

Strutting is widely used in the construction of floors, to provide additional strength. Two typical systems, herring-bone and solid, are shown here, together with the method of introducing sound-insulating material.

available as prepared floor boards, either square-edged or tongued-and-grooved. The common woods are whitewood, redwood, maple, oak, gurjun and Rhodesian teak. The boards should not be more than 5in. wide, to avoid open joints through shrinkage. Stock sizes are from ¾ to 1¼in. thick and from 4 to 7in. wide. It is common to have a counter floor of whitewood and to cover it with thinner hardwood boards as parquetry. Sometimes the counter floor is laid diagonally across the joists.

Wood floors are distinguished as single, double and framed. *Single* floors consist of common joists only, and present no difficulties except in the trimming for openings at fireplaces etc. The ends of the joists may rest on wall plates, to distribute the load, or they may be built into the brick walls. Ground floor joists are supported at intervals on sleeper walls, hence joists about 2in. by 5in. are commonly used. For first and succeeding floors, the sizes vary according to the span between the supporting walls.

Double floors are used when the span is over about 16ft. That is to say, binders are placed in suitable positions to carry the common joists. This type of floor may be up to 24ft. span for the binders. Strutting is often used to stiffen and strengthen the joists, and may be solid or herring-bone. The illustration also shows a method of insulating against sound. Slagwool is the best material for this type of insulating, but there are many other methods. Cabot's quilt is often used either between joists and ceiling or between joists and flooring. The trimming round a fireplace requires to be specially treated. The two trimming joists are thicker than the common joists to carry the weight of the trimmer, which in turn carries the trimmed joists. A tusk-tenon joint is the best, but alternatively the ends are often housed for half the depth. The brick trimmer-arch is often replaced by concrete, and sometimes by a steel bridge. See FRAMED FLOOR.

FLOOR JOINTS, see JOINTS.

FLUID FLYWHEEL. A device for transmitting, through the medium of oil, power from one to another of two shafts in alignment. In some types of road vehicle, the clutch is replaced by a fluid flywheel (Fig. 1) the drive being transmitted by the centrifugal force of rotating oil instead of by friction. The principle is similar to that of a turbine or a water wheel. The weight or pressure of the water on the vanes turns the wheel or turbine, thus driving the machinery. In the fluid flywheel oil takes the place of the water.

The component parts of a fluid flywheel are two castings, termed rotor and impeller (Fig. 2). The driven member, shown on the right in the illustration, is mounted on the gearbox shaft in such a manner that it is free to rotate independently of the driving member (left). It will be seen that a series of cup-shaped channels or cells is radially cast on the

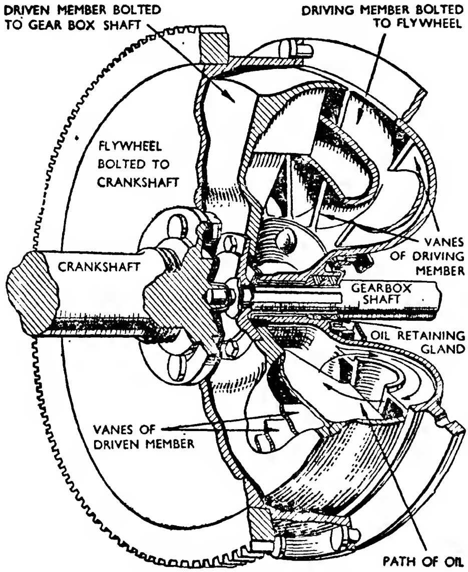


Fig. 1. Sectional view of a fluid flywheel as fitted to various road vehicles.

side of the driving member and facing similar channels on the driven member.

When the vehicle is stationary with the engine ticking over, or idling, the driving member is rotating slowly with the result that the oil in the channels will tend to flow to the periphery. Since the driven member is stationary the fluid will flow back through the channels of the stationary member to the centre, to be thrown out again by the driving section. In addition to throwing the fluid outwards the rotation of the driving member also carries the fluid round with it in its direction of rotation so that the driven member will tend to rotate. At low engine speeds, only a small centrifugal force is set up, so that there is little tendency for the driven member to rotate and slip will take place. As the speed of the engine, and therefore of the driving member, increases, the force with which the fluid acts on the opposite set of vanes will also increase, and slipping will gradually decrease until a point is reached at which the two members of the flywheel are rotating at almost equal speed, only slight lag on the part of the driven member then taking place.

The fluid flywheel is not suitable for use in conjunction with the conventional type of gearbox, since, even at low speeds, there is sufficient drag on the rotor and gearbox shaft to render gear-changing very difficult. It is, however, an ideal combination when used in conjunction with gearboxes of the epicyclic, or pre-selector, type, and one car manufacturer has employed this method for many years.

FLUORESCENCE. The emission of light by various substances when exposed to invisible radiations, such as ultra-violet rays or cathode rays. The energy of these radiations is absorbed by the substance and converted into light rays of a longer wave-length.

FLUORESCENT SCREEN, see CATHODE-RAY TUBE.

FLUORINE (F). Atomic no. 9; atomic wt. 19·0; a pale yellowish gas; m.p. −233 deg. C., b.p. −187 deg. C.

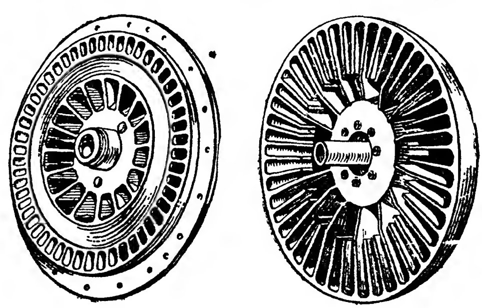


Fig. 2. Two castings, impeller and rotor, main parts of a fluid flywheel.

It has great chemical activity, reacting explosively with hydrogen to form hydrofluoric acid HF, a liquid used to etch glass; the vapour of HF also attacks glass. Fluorine is monovalent, as shown by this compound, and by fluorspar, or calcium fluoride, CaF_2, a common mineral used as a flux.

FLUSH DOORS, see Doors.

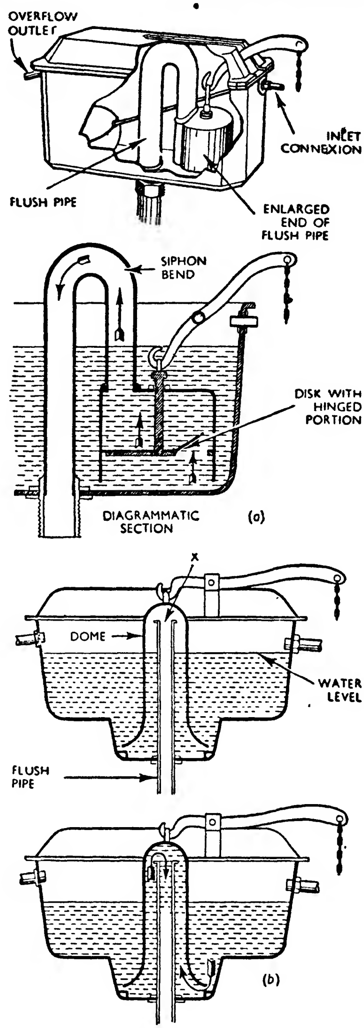
FLUSH JOINTS, see Pointing.

FLUSHING CISTERN. A tank containing water for the purpose of flushing away waste matter from a sanitary appliance. Today, all w.c. flushing cisterns must be of the siphonic "water-waste-preventer" type, of which there are various kinds. They differ, however, only in the way in which the siphonic action is initiated.

In one type, (a) in the illustration, when the handle is pulled down sharply, the arm raises a copper disk which operates within an enlarged chamber at the end of the flush-pipe. As the disk is raised, the body of water above it is projected upwards and over the siphon bend to fall down the flush-pipe. Thus siphonic action is caused and, so that the rest of the water in the cistern can follow round the siphon bend, part of the copper disk is hinged and is easily raised. The force of this upward-moving water supports the disk at the top of the chamber until the flush ceases when it falls slowly back to its original position.

Another widely used type of flushing cistern is shown at (b) in the illustration. This is usually manufactured of cast-iron throughout; it is a more sturdy type of cistern but is rather noisier in operation than the kind previously described. Here, the pulling of the handle lifts a heavy dome situated in the centre of the cistern and it is on releasing the handle that siphonic action is started. As the dome drops back into position, the body of air under the top of it is forced rapidly down the flush-pipe in which a negative air pressure, therefore, is momentarily created.

At the same time, the speed of the dome's descent causes the increased



Operation of flushing cisterns is clearly depicted in above diagram showing two types in common use.

volume of water now under it to be trapped. Little of it has time to creep back under the bottom edge of the dome, so that it surges up to occupy the space marked X where, of course, it enters the top of the flush-pipe and siphonic action begins. This speedily discharges the cistern. The dome,

when at rest, is supported on projections, or nibs, on its edge, or ledges formed on the bottom of the cistern, so that there is always a clearance for the water to pass into the dome.

The water level is maintained by means of a ball valve and all types should be fitted with an overflow pipe. See BALL VALVE.

FLUTTER. Oscillation of parts of an aircraft's structure which may occur in some conditions of flight unless special precautions are taken. An example is the case of tailplane-elevator flutter. If the tailplane receives a momentary high upload, due to some disturbance, it will deform slightly and the tips will be bent upwards. The elevator will try to stay in its original position, owing to its inertia, and will therefore be at a downward angle relative to the tailplane. This elevator deflection gives rise to a nose-down pitching moment on the tailplane, which will reduce its angle of incidence. This in turn causes a download on the tailplane and a consequent bending down of its tips. The elevator again lags behind, and so the process goes on.

The tailplane, like all structures which are not completely rigid, has a natural frequency of vibration, and if the speed of the aircraft is such that the frequency of the oscillations coincides with the natural frequency of vibration of the tailplane, the amplitude of the oscillations will build up to high values and lead to failure of the tailplane. This condition is known as resonance.

In such a case, flutter is prevented by mass balancing of the elevator so that it does not lag behind the tailplane in any vibrations that may occur. See MASS BALANCE.

FLUX (Elec. Engineering). See ELECTRICAL FLUX-DENSITY.

FLUX (Metallurgy). A substance which, when added to a solid, increases its fusibility; used in a variety of processes such as smelting, alloying, soldering, brazing and welding.

In smelting processes, fluxes are used to remove, or prevent the formation of, oxides or dross. They combine with, and consequently remove, the earthy substances present in the ore, which would otherwise hinder reduction of the metal, or else in some measure prevent the separation of the metal after reduction. The combination of the flux with such material produces a readily fusible slag which separates easily. The majority of fluxes may be classed as (a) acid, or (b) basic. The acid fluxes, e.g. silica, combine with metallic oxides, whereas basic fluxes are used if the ore contains large quantities of siliceous matter. Lime, dolomite, iron oxides and alkali carbonates are all well-known basic fluxes.

METAL OR ALLOY	FLUX
Copper, brass, bronze etc.	Borax, Borocalcite, glass, salt.
Lead and its alloys.	Sal Ammoniac, Zinc Chloride
Magnesium Alloys.	60 per cent Anhydrous Magnesium Chloride 40 per cent common salt.

In alloying, to be satisfactory, a flux must be fluid at the melting point of the alloy with which it is employed, and be able to dissolve considerable quantities of any oxide formed. In addition, a flux may act as a cover, so that the liquid metal does not come into contact with the atmosphere, thus preventing the formation of any dross. The purpose of a flux in this case, is, therefore, to clean the liquid metal and so promote a greater fluidity. Some of the more common fluxes used in alloying are given in the above table.

Soldering fluxes are intended to promote the formation of an actual alloy between metal and solder; as this can take place only if the surfaces are perfectly clean, the function of the flux is to prevent, by excluding air, oxides, oils, or other impurities from

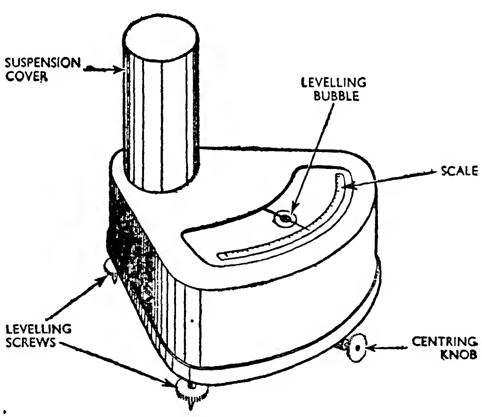
weakening the joint. Oxide films prevent the metal from flowing freely. Resin, zinc chloride and sal ammoniac are commonly used as fluxes for soft soldering; for brazing (hard soldering) powdered borax is generally employed. A mixture of equal parts, by weight, of borax and potash, melted and subsequently powdered when cool, also gives good results. For electrical work, a less acid substance is desirable, and various proprietary soldering pastes are used.

Fluxes used for welding depend largely upon the metal. For aluminium, mixtures of chlorides and fluorides are used; for copper, borax; and for iron, alkali carbonates may be employed. In metallic-arc welding, the rod may have a coating of flux. Not only does a flux reduce the risk of absorption of atmospheric gases by the weld, it also hinders volatilization of alloying elements. It is desirable that the flux be non-corrosive, so that any which remains in the joint will not lead to trouble afterwards. Easy removal of the flux after joining is also important.

Welding fluxes for iron and steel are generally composed of fine, clean sand or borax, which melts at a temperature below that of the welding heat; it is sprinkled on the edges when a yellow heat has been attained. Borax should be burned before use; it should be melted in a crucible, poured out so as to spread over a flat surface, and, when cool, ground into a powder. For the welding of tool steel, a flux composed of 12 parts of borax to 1 part of sal ammoniac is used.

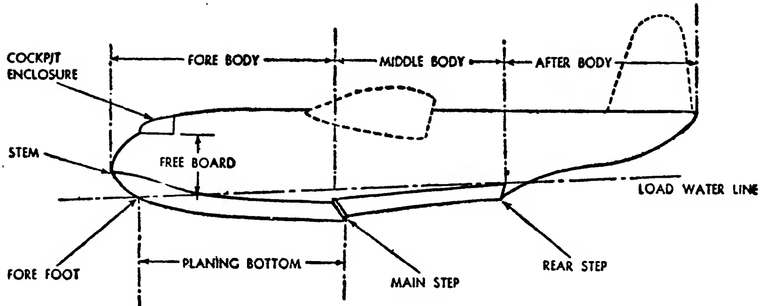
Aluminium welding fluxes dissolve the layer of oxide which forms along the edges to be welded; they also protect the newly welded metal from the action of the atmosphere. A convenient flux for use with aluminium and its alloys when the melting point is about 1110 deg. F., is a mixture of lithium chloride, potassium chloride, potassium fluoride and potassium bisulphate, which effectively dissolves any aluminium oxide formed and lowers the fusion temperature. Castings having sand on their surfaces need special care; a sand-removing flux is essential, otherwise the silicon in the sand will be passed into the aluminium, reducing the strength of the latter. A flux made of potassium chloride or fluorspar is suitable; it may be smeared as a paste on the surfaces concerned, or the parts to be welded may be heated and the flux sprinkled on the joint. A better method is to heat the welding rod and then dip it in the flux, which will gradually cover the surface of the rod like a varnish. Fluxes are also used in galvanizing and hot-tinning

FLUXMETER. An electrical instrument, having no control on its moving parts, which is used to measure changes in the flux linking a coil. A ballistic galvanometer (q.v.) may also be used for this purpose. The appearance of a typical fluxmeter is shown in the accompanying diagram.



In fluxmeters of this type, the pointer will stop anywhere on the scale and the instrument requires very careful levelling before use. Provision may be made for returning the pointer to zero when desired, but this is not essential.

FLYING BOAT. A type of aeroplane specially constructed to enable it to



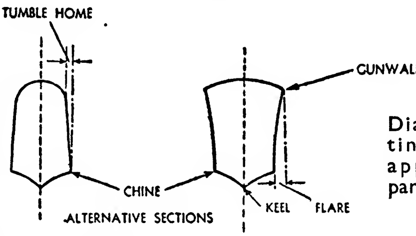


Diagram indicating the names applied to the parts of a flying-boat hull.

alight on, and take off from, water. The main body serves as fuselage to house passengers, crew etc. and provides buoyancy when the aircraft is at rest on water. The illustration shows a typical flying-boat hull and indicates the terms used to denote its main features.

FLYING SHEAR. A machine used in sheet-metal production for cutting-up long lengths into sheet sizes, the speed of operation being synchronized with the speed of the final mill-stand. A high degree of precision must be observed to give dimensional accuracy to the sheared product. See CONTINUOUS-ROLLING.

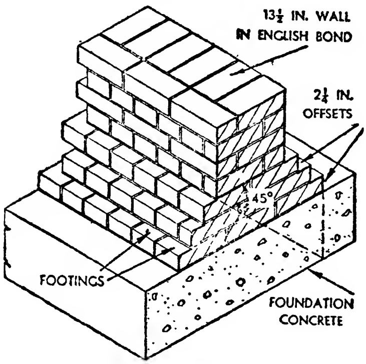
FLYWHEEL. A heavy wheel secured to the crankshaft of an engine to smooth-out the power impulses of the piston and, by stored energy in the form of momentum, to keep the crankshaft turning during the interval between power strokes. In a single-cylinder four-stroke internal-combustion engine these occur only once every four strokes of the piston, i.e. one to every two complete revolutions of the crankshaft. If the engine is designed to run at low speeds, a relatively heavy flywheel is necessary, but in a high-speed engine, only a light flywheel is required. Flywheels are usually made of cast iron, though in small engines, such as are fitted to motor cycles, steel is sometimes used.

In road vehicles, excepting motor cycles, the flywheel usually carries the clutch (q.v.) by means of which the drive is transmitted, through the gearbox, to the road wheels. Another type of flywheel, the fluid flywheel in conjunction with a special kind of gearbox, is sometimes used, however, and this makes a clutch unnecessary. See FLUID FLYWHEEL.

FOCUS. The point toward which rays of light from an object converge when they pass through a lens, so as to form an image. The position of the object is the *conjugate* focus; an image would be formed here of an object placed at the other focus. The *principal* focus is the point toward which rays parallel to the axis of the lens converge after passing through the lens.

FOOT-CANDLE. A unit of illumination. It is the illumination produced on the inside surface of a sphere, two feet in diameter, when a standard candle is placed at its centre.

FOOTING. A course of bricks which projects on each side of the base of the walls so that the weight of a building may be transmitted to the concrete base over a larger area than that represented by the net thickness of the wall. To effect this distribution, the bottom course of bricks is twice



In order to spread the weight of a building over a wider area, footings are constructed at the base of walls.

the thickness of the wall above, and contains as many courses as there are half-bricks in the thickness of the wall. Footings provide minimum and uniform settlement of the walls of a building, and stability against overturning.

FORGE BRAZING, see BRAZING.

FORMALDEHYDE (HCHO). A colourless gas soluble in water. When combined with phenol or urea it forms plastic resins used widely in industry. It is a powerful antiseptic and is also largely used in a 40 per cent solution in water under the name of formalin.

FORMALIN, see FORMALDEHYDE.

FORM CUTTER. A special cutter used for milling workpieces which have an irregular profile, the edges being shaped to the finished outline of the work. In this operation, known as form milling, the cutters are variously called form cutters or formed cutters; although some confusion between these terms exists, the latter is reserved by some engineers for cutters in which the teeth are backed off or relieved so that they can be sharpened on a grinding wheel, while "form" is used as the general term for all cutters of this type.

Such cutters are largely used for the machining of small components of typewriters, duplicating machines, sewing machines etc., as well as in ordnance manufacture and munition work.

From their simplest shapes, i.e. plain concave or convex profiles, form cutters may range over a large variety of profiles which are used for many different articles.

FORM DRAG, see DRAG.

FORME. A term used in printing to describe the complete composite page or sheet of type and/or pictures made-up in the pre-requisite design for printing. See CHASE.

FORMED CUTTER, see FORM CUTTER.

FORM FACTOR. The R.M.S. value of an alternating electrical quantity divided by its mean value. For a sine wave, the form factor is 1·11. It should be noted that the mean value is the average of a half cycle. See ALTERNATING CURRENT and R.M.S. VALUE.

FORMING TOOLS. Tools in which the cutting edge is ground to a special profile to facilitate the quick and accurate machining of difficult or unusual shapes. Forming tools may be used in lathes and planing,

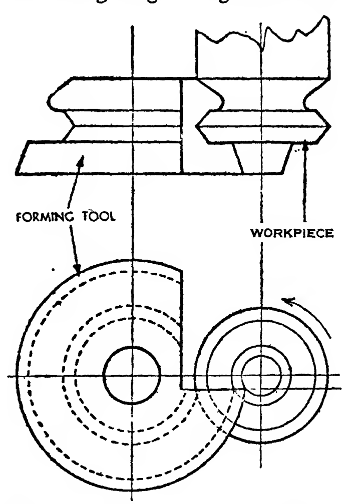


Fig. 1. Forming tools are used in machining difficult shapes, as a rule on lathes or planing machines. Above is shown a tool of the vertical type.

shaping or slotting machines, but chiefly in the first two, for which they are generally made either straight or flat. If the tool is not likely to be much

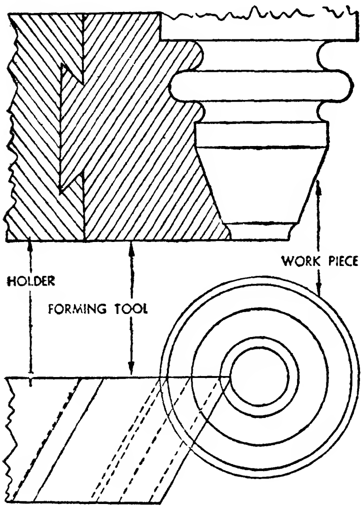


Fig. 2. Diagram showing application of a forming tool of the circular type. Note that the shape of the tool is negative to that required in the work.

used, it can be made solid; alternatively, a flat-formed blade may be fastened by bolts on to a holder, the blade constituting the removable portion.

A straight, vertical forming tool frequently used with automatic turning machines is shown in Fig. 1. The circular tool is usually preferred to the straight variety—especially with automatic screwing machines—because duplicates are more readily made from the master tool and because it can be ground again and again without alteration to its shape. The circular type is illustrated in Fig. 2.

If the shape is to be preserved in the straight type through successive regrindings, it will be necessary for the cross-section to be quite uniform within the desired limits. In another type of forming tool, the cutting edge, instead of rotating inwards towards the centre of the workpiece, moves along a line tangential to the surface to be formed.

FORM MILLING, see FORM CUTTER.

FORMWORK. Temporary structures of wood or sheet metal which hold concrete in place until it has hardened sufficiently to support its own weight and any superimposed loads. As the resulting contour of the concrete depends upon the exactness and rigidity of the formwork, it must be erected strongly enough to carry the entire weight of the concrete without deformation or deflection.

Formwork must be constructed so that it can be removed or taken apart with the least amount of labour, wastage of material and harm to the concrete. The term *shuttering* is often used. See TEMPORARY TIMBERING.

FORWARDING (Bookbinding), see BOOKBINDING.

FOUCAULT CURRENT, see EDDY CURRENT.

FOUNDATION. The portion of a building resting upon soil or rock; the term is also applied to the soil or rock immediately below the base of walls and piers. If the loads of a building exceed the bearing capacity of the material upon which the structure rests, the walls will fall. To avoid this, a concrete bed is formed to provide a non-settling base upon which to construct the footings.

The width of the concrete foundation is determined by the bearing capacity of the soil, and it should be such that the loads will be equally distributed over an area of ground which will safely support them. The concrete should be of such a thickness that there will be no likelihood of fractures occurring in it. Where walls are to be built on soft, marshy, or built-up ground, a special treatment by a system of piling, or the construction of a reinforced concrete raft, is often necessary, and the term *pile* foundation is then applied. See FOOTING.

FOUNDRY WORK. The melting of metal and subsequent pouring of the liquid metal into moulds to form castings of the desired shape. Almost any shape can be cast, in a wide

variety of metals, in sizes ranging from a fraction of an ounce to many tons. Foundries may be divided broadly into the ferrous and non-ferrous types; i.e. those which use iron or steel and those which use the non-ferrous metals or alloys. They can be further subdivided according to the types of casting made and the moulding methods employed.

The majority of foundries use sand for making the moulds, but a few use metal moulds, or dies, into which the liquid is either poured freely to make gravity die castings or forced under considerable pressure to form pressure die castings. Foundry work consists of a number of distinct trades, of which moulding is probably the most important. This is the shaping of a hollow space in sand, into which the liquid metal is poured to form the casting. For this the moulder requires a pattern, which is afterwards withdrawn, leaving a cavity of the desired shape. Where a mould cannot be made from a single pattern, additional patterns known as core-boxes are used.

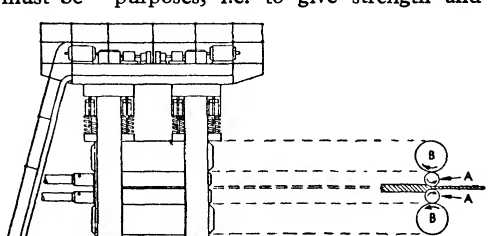
Channels known as runners, risers and gates are also needed to lead the molten metal to the mould and to provide a reservoir of liquid metal. Green sand, dry sand and loam are the materials most commonly used for moulds. Green-sand moulds are formed from moist sand; they need no drying and may be used immediately they are made. Dry-sand moulds are similarly formed, but the faces of such moulds are covered with a refractory coating, and they must be baked hard and dry, before casting. Loam moulds are prepared from a relatively wet and very plastic sand, and must also be dried before casting. Loam moulds are not usually made by a pattern, but are shaped by a template, or strickle board (q.v.), rotated about a centring spindle. The metal may be melted in furnaces of various types. A simple shaft furnace, known as a cupola (q.v.), using coke as a fuel, is generally employed for cast-iron. Modern high-duty and other special cast-irons, however, are sometimes melted in rotary furnaces. The non-ferrous metals are generally melted in crucible furnaces ranging in metal capacity from a few pounds to one ton, heat being supplied by coke, oil, gas or electricity. The crucible or pot which contains the metal is usually made of graphite or fireclay for high-melting-point alloys such as brass or bronze. Iron pots, which are cheaper and more durable, may be used for metals melting at low temperatures, such as tin and lead.

The liquid metal, however melted, may be run direct into moulds carried on conveyor belts beneath the spout of the furnace. It is more usual, however, to carry the metal to the mould in a ladle or shank. A ladle is used for large castings and has to be transported about the foundry by mechanical means. Shanks are employed for smaller castings and can be carried by hand. See DIE CASTING.

FOUR-ELECTRODE VALVE, see RADIO VALVE and TETRODE.

FOUR-FOLD RULE, see TWO-FOOT RULE.

FOUR-HIGH MILL. A type of rolling mill, for the production of sheet metal, in which, as is shown below, there are two work-rolls in a vertical plane, and two others, one above and one below, for backing-up purposes, i.e. to give strength and rigidity to the work-rolls. In developing this type of mill, the diameter of the work-rolls was reduced, since for any given reduction the load is



Four-high mills have two work-rolls, A, and two backing-up rolls, B.

directly proportional to the square-root of the roll radius while the diameter of the backing-up rolls was increased, within limits, to give maximum reinforcing strength.

Heavier reduction, i.e. greater reduction in the thickness of the metal being rolled, is therefore possible with this design, while at the same time the possibility of roll breakage is decreased. Increased rolling speeds are also more readily obtained with the four-high mill. See TWO-HIGH MILL.

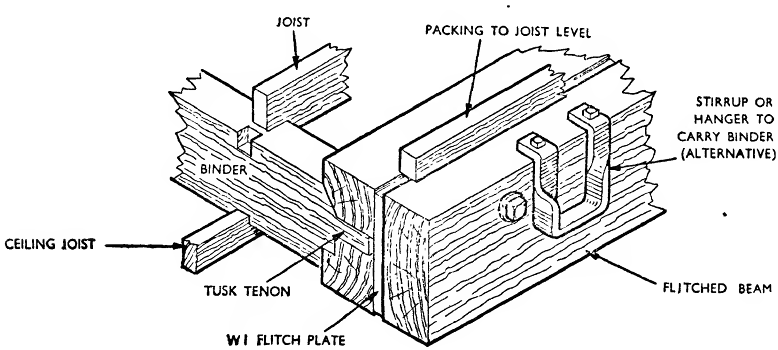
FOUR-WHEEL DRIVE. A system of imparting the drive of a road vehicle to all four wheels. The engine, clutch and gearbox are of orthodox design, but the gearbox drives a sprocket housed at its rear. The sprocket in turn transmits the drive through a chain to a chain wheel mounted on a differential casing.

From the end of this differential two propeller shafts transmit torque to the two axles. The rear axle is of the normal live-axle type, but the front axle, in addition to housing the differential, reduction gear etc., has universal joints (q.v.) situated at its ends to allow movement of the wheels for steering purposes.

FRAME AERIAL. A winding in radio also termed a loop aerial, usually on a frame, but occasionally self-supporting, serving both as an aerial and as part of a tuned circuit. Such a device possesses directional properties and, in some domestic receivers, is used instead of a more conventional long wire aerial for convenience and to make a set readily transportable. In commercial use, it forms the basis of direction-finding (q.v.).

FRAMED FLOOR. A floor subdivided into bays, by introducing main and secondary beams to reduce the span of large floor areas. The secondary beams are placed at right-angles to, and are connected to, the main beams. The lower portion of the floor beams which extend below the ceiling level is usually encased in concrete, for steelwork, or firred out with pieces of timber to form a ground for fixing the plasterwork.

Framed wood floors are seldom used in modern buildings, as they have been superseded by steel and concrete. The illustration shows the details for a large floor, including flitched beam, binder, common joists and ceiling joists. The binder may be tusk-tenoned into the beam or it may be carried by a stirrup, as shown. The flitched beam is formed of two 12 in. × 6 in. timbers with a wrought-iron plate, and is used for large spans to carry heavy loads.



FRAMED FLOOR CONSTRUCTION

In buildings having large floor areas, supplementary beams are fitted at right-angles as shown in order to reduce the span to be covered with beams or joists.

FRAMED STRUCTURE. A number of straight members so arranged and fastened together that

the stresses in the members are in tension or compression. Since a triangle is the only geometrical figure which cannot alter its shape without a change taking place in one of its sides, a framed structure is built up of a number of triangles framed together. A roof truss is a typical example.

FRAMES AND FINISHINGS, see DOORS.

FRAUNHOFER LINES. The dark lines in the solar spectrum discovered by Wollaston and investigated and named by Fraunhofer. They are due to absorption by the incandescent gases of the solar atmosphere and more than 5000 of them have been identified with known chemical elements. The principal lines are:

Line	Wavelength in Angström Units	Due To
B	6870	Oxygen
C	6563	Hydrogen
D_1	5896	Sodium
D_2	5890	
D_3	5875	Helium
E_1	5270	Iron
E_2	5269	
F	4861	Hydrogen
G^1	4340	
G^2	4308	Iron
H	3968	Calcium
K	3933	

Lines A′ and A″, with wavelengths of 7621Å and 7594Å respectively are due to oxygen in the atmosphere of the earth. See SPECTROSCOPY.

FREE-WHEEL. A device, usually arranged on the principle of the pawl and ratchet, which permits the transmission of power in one direction only. When, for any reason, the speed of the driven member becomes greater than that of the driving member, the former overruns the latter and free-wheels. Pedal-cycle transmission is the best-known example of this system.

Free-wheels are also fitted in some cars. The free-wheel comes into operation whenever there is a tendency for the road wheels to overrun the engine, thus allowing the vehicle to coast. Provision is made, usually in the form of a separate control in easy reach of the driver, for a positive drive when required, the free-wheel being put out of action. See RATCHET DRIVE.

FREEZING MIXTURE. A mixture usually formed by adding one part of salt to three parts of finely ground ice; the temperature of the mixture falls to about −20 deg. C. Many other salts have the same effect, which is due to the depression of the freezing-point (q.v.) caused by salts in solution.

FREEZING POINT. That temperature at which a liquid becomes solid. The freezing-point of a liquid is lowered if a substance is dissolved in it. This is known as the depression of the freezing point, and, for a given solvent, is porportional to the molecular concentration of the dissolved substance. The depression produced by dissolving 1 gram molecule in 100 grams of solvent is called the molecular depression constant.

FRENCH POLISH. A bright finish for hard timbers. It is satisfactory for internal use but soon deteriorates on exteriors unless protected by a coating of elastic oil varnish. The bare timber of surfaces to be polished should be finished with a joiner's steel scraper; a coating of shellac, dissolved in commercial alcohol, and stain soluble in alcohol is brushed on to the surface with a soft compact camel-hair brush to counteract the absorbent nature of the wood.

When dry, the surface is cut down with a fine-grained glass-paper and filled with a paste made from some inert mineral pigment such as china clay, whiting etc., and the liquid used for the previous coating. This, when rubbed into the surface across the grain with a pad or soft cloth, fills in the small cavities of the timber and, when dry, is cut down with fine abrasive paper. A substantial film of shellac is then established by repeatedly coating the surface with a slightly thicker clear solution of

shellac, applied with the brush, and cut down with fine abrasive paper between the coatings.

Having established the film the final polish is obtained by preparing a "rubber". This consists of a wad of cotton wool charged with the shellac solution and placed in the centre of a small piece of soft cotton cloth; the edges of the cloth are bunched together and the whole twisted into the form of a tight bag from the bottom of which the polish exudes as pressure is exerted.

A little linseed oil is applied with the finger-tip to the wet surface of the pad to prevent sticking; the pad is then passed over the work with circular sweeping strokes until a brilliant gloss is established. Satisfactory polishing can be executed only in a dry atmosphere of from 60 to 70 deg. F. See SHELLAC.

FREQUENCY. The number of complete vibrations (cycles) that occur in a unit period of time, usually one second. The standard frequency for electricity supply by A.C. mains in Britain is 50, that is to say, 50 cycles per second (c/s), though other values are sometimes encountered (see ALTERNATING CURRENT). In radio work, however, the number of cycles per unit of time is usually very large and it is, therefore, the practice to express frequencies in kilocycles (thousands of cycles) per second, or megacycles (millions of cycles) per second. Radio frequencies are often divided into bands, most of which possess distinctive propagation characteristics.

FREQUENCY CHANGER. An electrical machine which is used for changing electrical energy at one frequency to electrical energy at another frequency. Such a machine does not necessarily contain moving parts.

In radio engineering a frequency changer is a device employed in supersonic heterodyne receivers. The carrier-wave frequency of a signal is changed to another frequency, known as the *intermediate frequency*, by superimposing on it a locally generated oscillation and by rectifying and filtering the resulting wave. The process of obtaining this new frequency is termed *heterodyne action.* See SUPERHETERODYNE RECEIVER.

FREQUENCY DISTORTION, see DISTORTION.

FREQUENCY METER. An electrical instrument for the measurement of frequency. A simple type consists of a number of weighted reeds, tuned to slightly different frequencies, which are excited by an electromagnet. The one whose natural frequency is nearest to the frequency of the current in the coil vibrates more than do the others.

FREQUENCY MODULATION. A method of modulating a radio carrier wave. Instead of transmitting intelligence by the more usual method of varying the amplitude of the radiated wave (amplitude modulation), it is possible to communicate by maintaining the amplitude of the wave constant and to vary its frequency in accordance with the intelligence to be communicated. See MODULATION.

FRICTION. The force which opposes any movement of one surface in contact with another surface. If a force applied to one of the two surfaces in contact is increased so as to cause a tendency to slipping, the frictional force will be equal to it up to a limit called the *limiting* friction; if the moving force is still further increased, slipping will result.

For two given surfaces, the ratio of the limiting friction to the normal friction is constant, and is called the coefficient of friction. The value of the limiting friction before slipping is called the *static* friction, and is greater than the value during slipping, known as the *kinetic* friction.

FRINGING (Elec. Engineering). The spreading of magnetic flux beyond the area of an air-gap. For example, in a salient-pole electrical machine the flux does not all go straight from the pole to the armature and cease abruptly at the edge of the pole. Owing to fringing, it thins-out gradually.

FRIT. Smelted enamel glass resulting from the melting together of the raw

materials of the smelter batch. Among enamellers the term frit is usually applied to the glass after it has been quenched in water and thus broken into small pieces suitable for grinding. It is in this form that enamel is sold or stored for long periods until required for grinding, immediately before application.

FRUCTOSE, see CARBOHYDRATES.

FUEL-FEED SYSTEM. The method by which fuel is fed to an engine. It is now the accepted practice to carry the fuel tank at the rear of a motor vehicle, and this necessitates some means of forcing the fuel up to the carburettor, which is situated at a higher level. This is done by pressure feed, i.e. by means of an autovac (q.v.) or some form of fuel pump, which may be mechanically or electrically operated. Gravity feed, in which the fuel tank is placed at a higher level than the carburettor, so that the fuel falls naturally to a lower level, was very common in the early days of flying and motoring. It is now rarely found, however, save in light aircraft and motor-cycles. See FUEL PUMP.

FUEL INJECTION. The injection of fuel directly into the cylinder, or into the eye of the supercharger, of a petrol engine instead of mixing it with air in the carburettor; a scheme adopted by some aero-engine manufacturers.

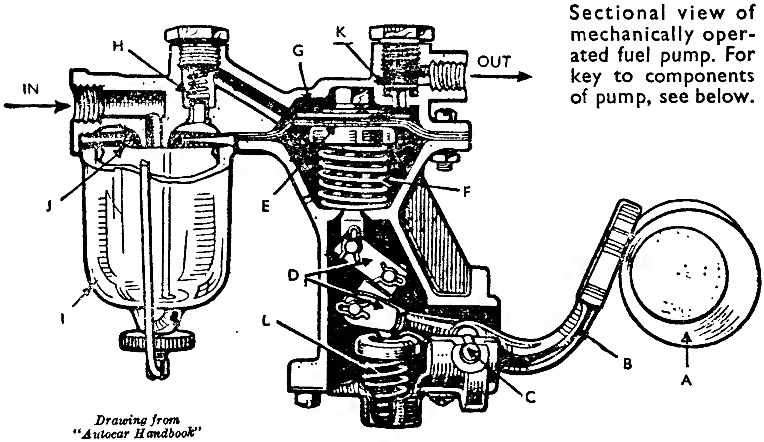
In an engine where fuel is injected directly into the combustion chamber, air alone is led into the cylinder by way of the inlet valve in the normal manner. The petrol supply is taken from the tanks to a reciprocating pump which has pistons and cylinders equal in number to those of the engine.

This pump delivers a suitable quantity of petrol to each engine cylinder when the piston is approaching the top of the compression stroke. The arrangement is very similar to that used in Diesel engines (q.v.). See also COMPRESSION-IGNITION ENGINE.

FUEL OIL, see FUELS.

FUEL PUMP (Auto. Engineering). A device used, on road vehicles having low-positioned tanks, to raise fuel and maintain an adequate supply to the carburettor. Two types of fuel pump are in general use: mechanical and electric.

The elements of a mechanical pump are shown in the illustration. The intake side of the pump is connected by a pipeline to the main fuel tank, the



Sectional view of mechanically operated fuel pump. For key to components of pump, see below.

A, cam; B, rocker arm; C, pivot; D, link mechanism; E, diaphragm; F, diaphragm spring; G, pump chamber; H, inlet valve; I, filter chamber; J, fuel filter; K, automatic fuel-outlet valve to carburettor and L, rocker-arm operating spring.

outlet side being similarly connected to the carburettor float chamber. The pump is operated from a cam integral with the camshaft. One end of a rocker lever is held by spring pressure on the profile of the cam, the other end being coupled by a linkage to the centre of the diaphragm. A valve on the intake side of the pump prevents the fuel from flowing towards the tank, while a second valve, on the outlet side, stops the fuel from being drawn back from the carburettor. All spirit delivered to the carburettor passes through a gauze filter into a glass bowl into which any sediment drops.

Principles of the Pump

The action of the pump is as follows: the cam, as it revolves, pushes a lever, which also controls the diaphragm, down against the tension of a spring. This creates a partial vacuum in the pump chamber and fuel is drawn up from the tank through the inlet valve. As the cam moves further round the lever falls back and releases the diaphragm which is forced upward by spring F and the fuel is forced through the outlet valve to the carburettor. When the float chamber is full a pressure is exerted on the upper surface of the diaphragm which holds it down against the spring. The linkage D now allows the lever to move without affecting the diaphragm until more fuel is required.

Electric fuel pumps are, broadly speaking, identical in function, with the exception that the diaphragm is actuated by electro-magnetic effort. Regulating valves are similarly incorporated to control the flow of fuel to and from the tank and carburettor. See AUTOVAC and FUEL-FEED SYSTEM.

FUELS. Substances, natural or artifical, which combine with oxygen with the production of heat. Fuels in use to-day can be divided into solid, liquid and gaseous, solid and liquid being frequently transformed into the gaseous state for convenience in use. The number of substances used as fuels is large and varied, but coal and petroleum are in the greatest demand.

Among the more important fuels are the following:

SOLID FUELS.

Wood. A low-grade fuel (low calorific value) which is still in demand in those parts of the world where its cost is not great. It is the raw material for the production of charcoal, and can be transformed into the gaseous state.

Peat. Low-grade fuel, used mainly in country districts for domestic purposes.

Brown Coals and Lignites. Mainly of local importance, although high-temperature carbonization will produce gas of low quality. For bituminous coals, their various qualities and uses, see COAL.

LIQUID FUELS.

Petrol. One of the more volatile fractions of petroleum; it is used in the internal-combustion engines of cars and aircraft, but also finds some use for domestic cooking, heating and lighting. See HYDROCARBON and PETROLEUM.

Paraffin. A fraction of petroleum, less volatile than petrol; it finds its greatest use as a motor fuel in farm tractors and small craft; also used for lighting and heating.

Diesel Oil. Low-grade petroleum, used in the compression-ignition type of engine for marine and other heavy-duty purposes, also for steam-raising in oil-fired boilers.

Fuel Oil. Crude petroleum, almost entirely confined to marine use in oil-fired boilers.

Among other liquid fuels coal tar, creosote, benzol and alcohol are the most important. Coal tar can be used for steam-raising, although it is not really considered suitable. In the future, however, it may be possible to use its products as diesel-engine fuel. Creosote, derived from coal tar, has already been used in internal-combustion engines.

Benzol, derived from coal, is mixed with petrol for its anti-knock properties.

Alcohol, which finds a slight use in small spirit stoves, can also be used in the internal-combustion engine. Mixed with petrol, it permits a higher

compression-ratio than petrol alone.

GASEOUS FUELS.

Natural gas. This may be used either for domestic purposes or in internal-combustion engines, but is of importance only in countries where it is easily obtained, notably in the U.S.

Coal Gas. A product of the carbonization of coal. It is used extensively for heating and cooking all the world over.

Water Gas. Carburetted water gas. It finds great use as town gas, but has to be mixed with coal gas before use.

Producer Gas. Produced by passing steam over red-hot coke, is not much used save in gas retorts, coke ovens, steelworks etc.

Blast-Furnace Gas. A by-product of iron-smelting, used mainly for steam-raising in factories where it would otherwise be a waste product.

Acetylene. Obtained by the action of water on calcium carbide, and used mainly for cutting and welding steel. It produces a very hot, localized flame when burned in pure oxygen (oxy-acetylene).

FULCRUM. The point on which a lever is supported, and around which it rotates or tends to turn.

FULLY FLOATING AXLE, see AXLE.

FUNDAMENTAL. Every complex wave-form can be analysed into a number of component sine waves of different frequencies, amplitudes and phases.

The principal component consists of a sine wave having the lowest frequency of the wave-form under consideration. This component is called the fundamental. The other components, having frequencies which are direct multiples of the frequency of the fundamental, are called *harmonics*.

FUNGOID GROWTHS. Parasitic growths; all timbers are liable to attack if placed in ill-ventilated or damp situations. The ripe spores or seeds, which are extremely minute, are airborne; if they settle on the habitually damp surface of timber when the temperature is right, they germinate and feed upon its fabric, bringing about premature decay.

Dry rot is possibly the best known, the use of unseasoned timber in badly ventilated positions being its most prevalent cause.

Its ravages are prevented to a large extent by the use of creosote upon all timber used as joists and upon the under sides of ground-floor floorboards. Coating with naphtha (q.v.), a liquid obtained by the dry distillation of coal and petroleum, is also a deterrent.

Proprietary materials of similar characteristics, containing salts of metals which immunize timbers from both vegetable and insect infection, can be obtained from most drysalters and paint merchants.

FURNACE. A heated chamber made in a large variety of styles for an immense range of processes, e.g. annealing, hardening of steel, rolling mills, forges, drawing operations, melting metals or drying and baking processes generally. Heat may be supplied by coal, coke, gas, oil, or electricity. Furnaces may be roughly classified, according to the number or positions of the doors and combustion chambers, into single-end and double-end types, the latter having doors at both ends.

Side-fired furnaces are never used when coal is the fuel to be employed; widths of 5 to 7 ft. can be satisfactorily heated, the waste gases being drawn under the floor of the heating chamber to assist in increasing the efficiency. For plates and certain types of large forgings etc., end-fired furnaces are employed, especially when the work, being short in relation to its depth, does not require a false arch.

Under-fired furnaces are useful for small work and are suitable for layout where firing can be done below the floor level, e.g. in a pit; as the roof of the combustion chamber in this type tends to get very hot, refractories of specially good quality have to be employed. When a very fierce heat is required, and the work will not suffer from being in contact with the flame, internally fired furnaces may be used;

this type is chiefly restricted to the liquid or gaseous fuels, so that no deposit of soot may occur on the work. Furnaces for forges, or for the heating of rods, rivets etc., may be of this variety.

Electric furnaces are of three general types: arc furnaces, induction furnaces and resistance furnaces. In arc furnaces the heat is generated by an electric arc between carbon electrodes. This, the hottest type, is now almost invariably used for melting metals or for smelting, i.e. extracting metals from their ores. It may be of the independent, indirect-arc or direct-arc type. The indirect-arc furnace normally consists of one or more arcs struck between electrodes independent of the charge, which itself may be non-conducting. The direct-arc furnace involves one or more arcs struck between the electrodes and the charge.

Various Types

The electrodes are generally of graphite or amorphous carbon, and the furnaces use alternating current. They can be made in sizes from a few pounds in capacity up to 100 tons, and they are used for melting almost every metal or alloy and for making ferro-alloys and electro-chemical products such as calcium carbide, phosphorus, carbon disulphide etc.

In induction furnaces the work to be heated may be connected directly to the circuit after the manner of the low-tension portion of a static transformer; such furnaces are used only for the melting of materials. High-frequency current, producing eddies (subsidiary currents) which heat the material to be melted, are now in use and form a further variety of electric-induction furnace. Resistance furnaces are of two chief classes. In one, the heating current is actually carried by the materials to be heated, with or without electrolysis; in the other, it is conveyed by a resister connected directly to the supply mains. In both types it is the resistance to the passage of the current, through either the charge or the resistor, which gives rise to the heat generated. Generally, resistance furnaces are used for work requiring comparatively low temperatures, e.g. the fusing of metals and alloys with low melting-points, and for general heating purposes.

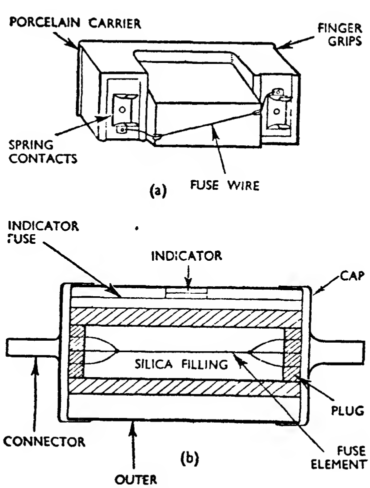
Annealing furnaces may use electricity or solid, liquid, or gaseous fuel, and operate at temperatures ranging from 200 to 1200 deg. C., the lower temperatures being necessary for metals of low melting-point or alloys such as zinc and aluminium, and the higher temperatures for alloy steels.

FURNACE BRAZING, see BRAZING.

FUSAIN. A dull, brittle constituent of coal (q.v.), resembling charcoal and having a fibrous appearance. Under the microscope it shows a cellular structure derived from the original vegetation from which the coal is derived.

FUSE. A device for breaking an electrical circuit when the current in it exceeds a predetermined value. The term is restricted to such devices as contain a fusing element, which, by melting, breaks the circuit.

In the accompanying diagram (a)



Above diagram shows, at (a) fuse of the rewirable domestic type for 10A. and 250 V. and (b) high-rupturing-capacity fuse fitted with a silver element.

illustrates a rewirable type of fuse which is commonly used for low powers.

The fusing current depends, chiefly, upon the diameter and material of the wire, but it is influenced by the length of wire, the design of the fuse carrier, the position in which it is mounted, and the time during which the current flows. For higher powers, the high-rupturing-capacity (H.R.C.) fuse shown at (b) in the illustration is preferred.

FUSELAGE. The main fore and aft part of the structure of an aeroplane; it houses the crew and the main load carried by the aircraft. Most single-engined aircraft have the engine mounted in the nose of the fuselage. In conventional designs the empennage (q.v.) is attached to the rear of the fuselage.

FUSIBLE METALS. The generic name given to a class of alloys whose chief characteristic is a very low melting-point, i.e., between 60 and 180 deg. C.

The majority of these alloys are composed of various proportions of bismuth, tin and lead; sometimes cadmium, and occasionally mercury, is added.

Newton's fusible metal consists of 50 per cent bismuth, 31·25 per cent lead and 18·75 per cent tin; it melts at 201 deg. F. Another alloy, Wood's metal, consisting of 50 per cent bismuth, 12·5 per cent tin, 12·5 per cent cadmium and 25 per cent lead, will melt at the very low temperature of 150 deg. F. An even lower melting point (113 deg. F.) can be obtained by the addition of mercury to a fusible alloy consisting of 50 per cent bismuth, 25 per cent lead and 25 per cent tin.

Fusible metals are very useful for automatic sprinkler heads, in which the increased temperature caused by a fire will cause the fusible metal to melt and so bring the sprinklers into action.

Some other uses are as plugs in steam boilers to protect the firebox from overheating should the water-level fall too low, and as fuses in electric circuits.

FUSIBILITY. The tendency of a substance to melt and change from a solid into a liquid state. Of all the chemical elements known, carbon appears to be the least fusible; i.e. it will withstand, without melting, a higher temperature than any other. A certain amount of heat is needed to effect the change: this is the latent heat of fusion; the actual temperature does not alter while the change from solid to liquid is taking place.

GABLE. The portion of the vertical, triangular piece of wall, situated at the end of a pitched roof, from the eaves to the ridge.

GAGGERS. In foundry work L-shaped pieces of wrought-iron, also termed *lifters*, used to provide reinforcement to the cope (q.v.) of a mould, as shown in the illustration. They are especially useful for deep copes that project into the drag, helping to ensure a clean lift without damage to the cope. In fitting gaggers, about ½ in. of sand is first placed on the pattern.

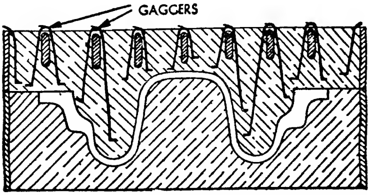


Diagram showing method of using gaggers, or lifters, to support a deep cope.

A number of gaggers of suitable length are hooked on the crossbars of the cope so that the horizontal portion rests on the sand. Before insertion, gaggers should be dipped in clay wash, so that when the cope is rammed the sand sticks firmly to them. Although a large stock of gaggers is carried in most foundries, extra ones of special

sizes may be made-up as required from wrought-iron rods.

GALENA (PbS). A common ore of lead; it crystallizes in the cubic system, is bluish-grey or black, and has a metallic lustre.

GALVANIZED IRON, TO PAINT, see PAINTING.

GALVANIZING. One method of depositing a coat of one metal upon another—usually zinc on iron or steel. The zinc coating is to prevent moisture reaching the surface of the iron or steel and so causing rust. Zinc is practically unrivalled for this purpose among all the usual commercial metals, since tin and lead give inferior results, while aluminium, though making a very good coating, is somewhat expensive.

In the galvanizing process the article to be coated is first pickled in sulphuric or hydrochloric acid, and then dipped into a bath of molten zinc which is covered with a layer of flux, usually ammonium chloride. The temperature of the bath varies from about 450 to 480 deg. C. Sometimes a small amount of aluminium is added to galvanizing baths; this has the effect of making the zinc more fluid, so that thinner coatings are produced. Galvanized coatings are highly weather-resisting and withstand the action of water well, especially when they are of adequate thickness, i.e. 0·001 in. or more. Thicknesses tend to be very irregular. Zinc coatings have a characteristic spangled appearance, and large spangles are usually indicative of a thin layer of zinc.

Both wire netting and single wire are galvanized in large quantities, and are run through the bath in a continuous process. Careful regulation of the speed at which the wire passes through the bath, and of the temperature of the molten zinc, is needed to give the best results. Usually, the wire passes through a flux before entering the galvanizing bath, and the film of oxide which forms on the surface of the zinc must be continually removed by skimming.

GALVANNEALING. A modification of the galvanizing (q.v.) process. Hot galvanized coatings, produced by dipping steel parts into molten zinc, tend to be brittle and to flake off if the coated metal is subjected to any bending. This is due to the formation of brittle intermetallic-alloy layers between the zinc coating and the underlying steel. The object of galvannealing is to improve the adhesion of the galvanized coating.

Galvannealing is usually applied to zinc-coated wire, where flexibility is required, and the process consists of passing the wire, immediately after galvanizing, through a furnace maintained at 650 to 700 deg. C. for a period of about 15 minutes. The coating then consists almost entirely of alloy, and although it may develop slight cracks when severely bent, it is much less liable to flake.

GALVANOMETER. An electrical instrument, used normally as an indicator of the presence of small currents, rather than as a means of measuring them. Galvanometers are commonly used to show whether a Wheatstone bridge is balanced or not. The construction of one type of galvanometer is the same as that of a moving-coil instrument. See MOVING-COIL INSTRUMENT and WHEATSTONE BRIDGE.

GANGAU, see IRONWOOD.

GANGING. The mechanical coupling in radio of adjustable devices in such a way that they can be operated by means of a common control; thus, switches or variable resistances can be ganged. In a tuned radio-frequency receiver it is convenient to adjust all tuned circuits simultaneously, by means of a single knob when selecting a programme. In a superheterodyne receiver, the local oscillator frequency adjustment is part of the tuning process and it is desirable that, for all signal frequencies, the difference between it and the signal-carrier frequency shall be automatically equal to the intermediate frequency. See SUPERHETERODYNE RECEIVER.

GANG RIVETING. A process whereby 10 to 15 flush-type rivets along a straight line and on flat

sections may be headed in one operation. Press-type methods are used, two anvils being adjusted to apply the appropriate pressure for various rivet sizes. While the heads are being formed, the sheets are firmly held by means of a pressure pad, consisting of two thin-edged rails on each side of the anvil. The anvils of one type of installation accommodate 10 5/32-in. flush-type rivets spaced ¾ in. or 16 ⅛-in. rivets spaced ½ in.

A wide combination of rivet patterns can be made, as the upper and lower anvils are quickly replaceable by means of two socket-head screws on each. On this type of machine, too, quite heavy punching and forming can be accomplished by replacing the riveting heads with heads for punching or press-countersinking single holes or gangs of holes, as the machine can be made to develop up to 50 tons pressure over the last ¼ in. stroke.

The main advantage of this method is speed, but it is also considered that the regular and smooth appearance of the riveted sheet is improved.

GANG SLITTER. A machine which, by means of parallel, rotating cutters, slits thin metal sheets or strips into lengths. The method is used in can-making (q.v.), where the blanks for forming must have good dimensional accuracy. This type of plant is also generally in use in strip-rolling in order to supply narrow-width material, as it is more economical to roll in multiples of a very narrow width and to slit, than to roll direct. An additional advantage of the slitting method is that gauge accuracy across the material can be more closely controlled; for certain purposes it is desirable to have sheared edges.

GARNET PAPER, see SANDPAPER.

GAS. The most fluid state in which matter is known to exist; a state in which the molecules have the greatest freedom of movement. A gas or vapour may consist of separate molecules of the element or compound concerned, or it may be a mixture of different molecules.

The fact that a gas can be compressed to a small fraction of its original volume shows that the molecules are widely separated. The diffusion of gases shows that they are moving. The higher the temperature of the gas, the greater the speed of the molecules. In a jar full of gas the movement of the molecules seems entirely to overcome the attraction of gravitation, but on a large scale this attraction does become apparent, and the air at the top of a mountain is less dense than at sea level.

All gases may be liquefied at a low temperature and under high pressure. The pressure of a gas in a closed vessel is due to the impact of the molecules against the sides of the container.

GAS-FILLED VALVE. A radio valve into which gas has been introduced for the purpose of obtaining special characteristics. Such valves, chiefly diodes and triodes, may be broadly divided into two classes:

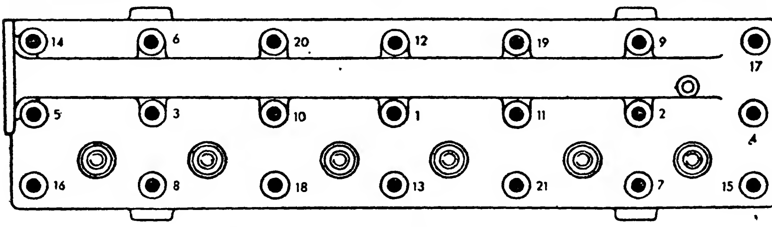
(1) The *hot cathode* type which includes diodes used for power rectification and triodes, or *thyratrons*. For further information on such diodes, see RECTIFIER and for details of gas-filled triodes, see THYRATRON.

(2) The *cold cathode* type which covers diodes used as voltage regulators and stroboscopic light sources and triodes whose chief applications are as trigger or relay devices.

GASKET. The jointing medium placed between two metal surfaces where a gas- or oil-tight joint is required. It is usually made of a thick sheet of asbestos between two thin sheets of copper.

The gasket used between the cylinder head and cylinder block of an internal-combustion engine is shaped to conform with the details of the design of the cylinder block, and has holes in it to correspond with cylinder bores and water-circulation passages. It also has smaller holes to allow the cylinder head holding-down studs to pass through it.

When fitting a new gasket, extreme care is needed to see that all particles of dirt are removed from the joint



TIGHTENING A CYLINDER HEAD

Plan view of a cylinder head for a six-cylinder engine, showing order of tightening holding-down nuts to ensure a gas-tight joint between the head and cylinder block.

faces. No jointing compound is required other than a smearing of grease or household soap. When tightening-down the cylinder head, all the nuts should first be run down on their respective threads until they just begin to grip and should then be tightened-up in the order shown in the accompanying diagram, which applies to a six-cylinder engine; the procedure, in general terms, is to commence with the centre stud and work outwards from it evenly in all directions, those at the ends being left till last, though naturally the manufacturer's instructions should always be followed.

GAS LAWS. Boyle's Law states that the volume of a given quantity of gas at constant temperature is inversely proportional to its pressure. Charles' Law states that at constant pressure the volume is proportional to the absolute temperature.

Combining Boyle's Law and Charles' Law, we get the equation $PV=RT$, where P represents the pressure, V the volume, and T the absolute temperature; R is a constant depending on the mass of the gas and its nature. Avogadro's Law states that equal volumes of all gases at the same temperature and pressure contain the same number of molecules.

These laws are true only when the gas is at a temperature much higher than that at which it becomes liquid. At lower temperatures it is necessary to take account of the attraction of the molecules for each other, and of the volume of the molecules. Gases such as carbon dioxide, oxygen and nitrogen at ordinary temperatures are chiefly empty space in which the small molecules are travelling at high velocities. At temperatures approaching the liquefaction of such gases, the laws connecting their pressure, volume and temperature are more accurately given by the van der Waals equation:

$$\left(P+\frac{a}{V^2}\right)\left(V-b\right)=RT$$

in which a is a factor depending on the mutual attraction of the molecules for each other and b is a factor depending on the actual volume of the molecules themselves. The equation thus modified holds good for gases at all temperatures.

GASSING. An effect which takes place in an electrical accumulator towards the end of the charging period. It is due to electrolysis (q.v.) of the sulphuric acid electrolyte. Hydrogen is evolved at the positive plates and oxygen at the negatives. These gases may form an explosive combination, so that naked lights should not be brought near to an accumulator on charge.

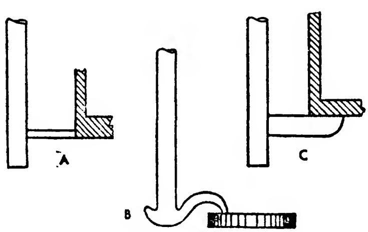
The amount of gassing gives a rough indication of the state of charge. When a cell gasses freely from both sets of plates the charging may be considered to be almost complete. See Lead-Acid Accumulator.

GAS THREADS. Standard threads for gas, water and steam piping. In Britain there are two series, known as the Whitworth and the British Standard Pipe. In practice there is virtually no difference in the medium sizes for pipes of nominal bores ranging from $\frac{1}{4}$ to $1\frac{3}{4}$ in., which are

probably the most commonly used. This type of screw thread was evolved because it was found that the ordinary Whitworth standard thread for nuts and bolts was too coarse to apply to piping.

GATE. In foundry work, a passage cut in a mould through which metal enters the mould cavity; the vertical portion of the gate is known as the down gate, or runner, and connects the runner bush either to the in-gate or direct to the casting. The in-gate connects the down-gate to the casting and may be of various forms, that in which the gate leads directly in to the side of the casting, as at A in the illustration, being preferred for most work.

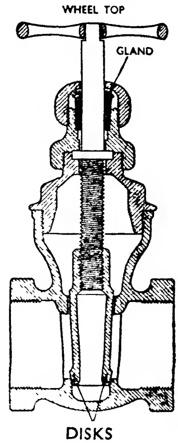
In some cases—for example, gear wheels with cast-in teeth—such a method is impossible. Horn gates as shown at B are then employed. Alternatively, if top gating is impossible, the casting may be run from underneath by means of a fountain



Types of gate used in foundry work.

runner as shown at C. In all cases it is desirable to leave a sump at the bottom of the runner, in which any sand dragged in by the metal is trapped.

GATE VALVE. A full-way control valve on heating and hot-water supplies in wrought-iron pipes. The valve is provided with either screwed female ends for connexion to wrought-iron tubing, or an adaptor for copper tubing. The diagram shows a gate valve with ends threaded internally. The principle is that of a disk, or gate, which is screwed down between two machined faces or seatings. The disk works on a screw or spindle having a wheel top which does not screw down, with a packing gland to prevent leakage.



In low-pressure water systems, stop-cocks and valves should be of the full-way type, to ensure the best possible flow.

Care should be taken not to force the disk into the seating. Damage is also caused by grit or rust finding its way between the disk and seating and thereby spoiling the machined faces.

GATHERING. Collecting, in correct sequence, the sections of a book, pamphlet or other printed work, preparatory to binding. The sections are arranged in sequence round a table and picked up by hand one by one. A quicker method is to seat the gatherers round a circular table and cause the table to revolve. The table revolutions are recorded mechanically and hence the number of complete units is known.

A straight and completely mechanical gatherer is used on large-edition work. Stacks of sections are arranged in sequence, each one under a suction separator. The bottom section is taken from the first-unit stack, deposited on a V-grooved channel and pushed along towards the receiving end by a bracket. A section is picked up from each unit in turn. In the case of a misplaced section, the whole machine automatically stops, and a red light appears over the offending unit.

GAUGE. The term may be used when referring to either a measurement or a measuring instrument. As a measurement, its use is common in connexion with width or thickness, e.g., the gauge of British railways, that is the distance between the rails, is 4 ft. $8\frac{1}{2}$ in. Sheet metal—copper,

tin, tinplate etc.—is spoken of as being of heavy or light gauge when referring to its thickness. There is also a wire gauge which forms an accepted standard by which wire can be known. Gauge standards in sheet metal and wire are usually a series of numbers so that the material is known as "16 gauge," "12 gauge" etc.

Gauges for measuring are made in a great variety of forms for many different purposes, which include measuring pressure, height, surface, depth, thickness etc. These instruments range from simple tools like the feeler gauge to the elaborate clock or dial gauges.

Where it is necessary that a number of continuously varying measurements shall be under the eye of one man, clock-type gauges are usually mounted on a panel and placed in a central control cabin such as is found in aircraft, ships and power stations. See LIMIT GAUGE.

GAUSS. A unit of magnetic flux-density. One gauss represents one line of force, or one maxwell, per sq. cm. of area perpendicular to the line. In transformers a flux-density of 10,000 to 14,000 gauss is commonly employed, while in generators, a density of 22,000 gauss, or 22 kilogauss, may be reached in some parts.

GEARBOX. The casing or box containing an arrangement of gear-

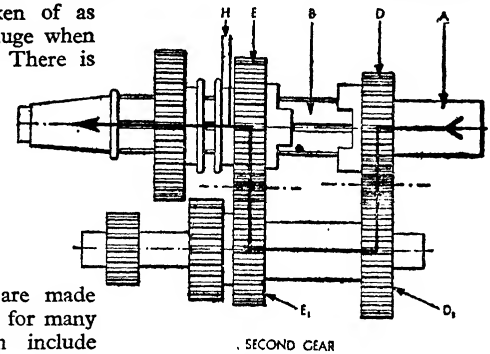


Fig. 2. Gears D and E having been disengaged, E and E_1 take up the drive through the mainshaft for second gear.

wheels. Gears are used in automobiles for converting the high speed of the engine into a lower speed with greater turning power of the propellor shaft. The power of modern lightweight internal-combustion engines depends largely on engine speed, and power falls off very rapidly as speed decreases, when, for example, a vehicle is climbing and the power is most required.

Different combinations of gear-wheels are therefore engaged to maintain the engine speed, these combinations being known as gear ratios; thus, if a gear-wheel having 15 teeth is engaged with a second wheel having 30 teeth, the smaller wheel will make two revolutions to one of the larger, and the gear ratio is then said to be 2 to 1. The smaller of the two wheels is known as a *pinion*. In a road-vehicle gearbox, there are usually three or four forward gears and one reverse gear.

A simple form of three-speed gearbox is shown diagrammatically at Fig. 1. There are three shafts: driving shaft, A; main shaft, B; and layshaft,

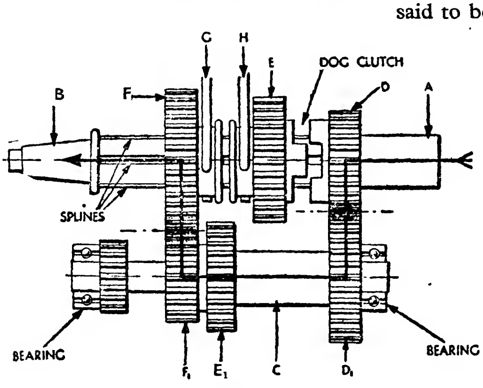


Fig. 1. Diagrammatic sketch of simple three-speed gearbox with first gear engaged.

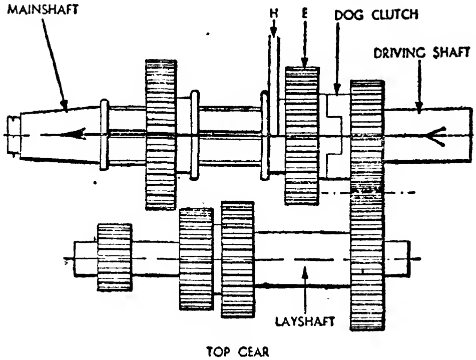


Fig. 3. In top gear, the drive is direct from driving shaft to mainshaft.

C. Supported by two ball-bearings at each end, the layshaft carries four gear-wheels of varying sizes. The short shaft, A, transmits power from the engine through the clutch. It has one gear-wheel, D, secured to it which is in constant mesh with D_1 on the layshaft. The wheel D has slots on that side facing the main shaft, into which fit corresponding teeth on gear-wheel E which slides on the main shaft. This form of coupling is termed a dog clutch. The main shaft is supported at one end by a ball race housed in the side of the gearbox, the other end being supported in a spigot bearing located in the centre of the driving shaft. The two shafts A and B rotate at the same speed only when the dog clutch is engaged; that is, in top gear. In all other gears they are disengaged and rotate at different speeds. The various gears are obtained by sliding the gear-wheels E and F along the main shaft, which is splined so that shaft and wheels, also splined, rotate together. The wheels are moved along the main shaft by operating selector levers G and H.

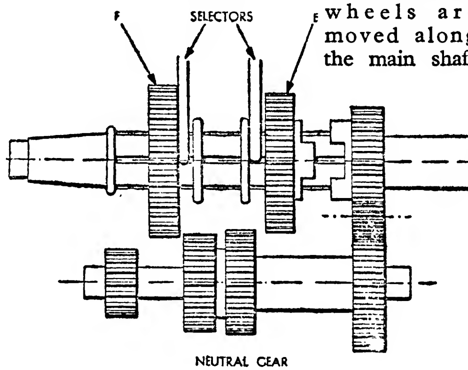


Fig. 5. With gears in neutral position, no drive is transmitted to mainshaft.

In Fig. 2 gear-wheel E is shown disengaged from D and engaged in *second gear*, with E_1; this is done by moving selector H to slide the gear along the shaft B. The main shaft now has a lower gear-ratio than when in top gear. The drive is transmitted from A to D, from D to D_1 through the layshaft to E_1 and through E to the mainshaft.

To engage *top gear* the lever H slides the wheel E along the mainshaft until the dog clutch is engaged (Fig. 3.). Both shafts are now locked together and the drive is direct from

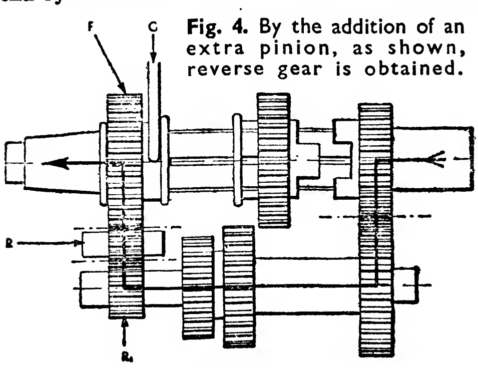


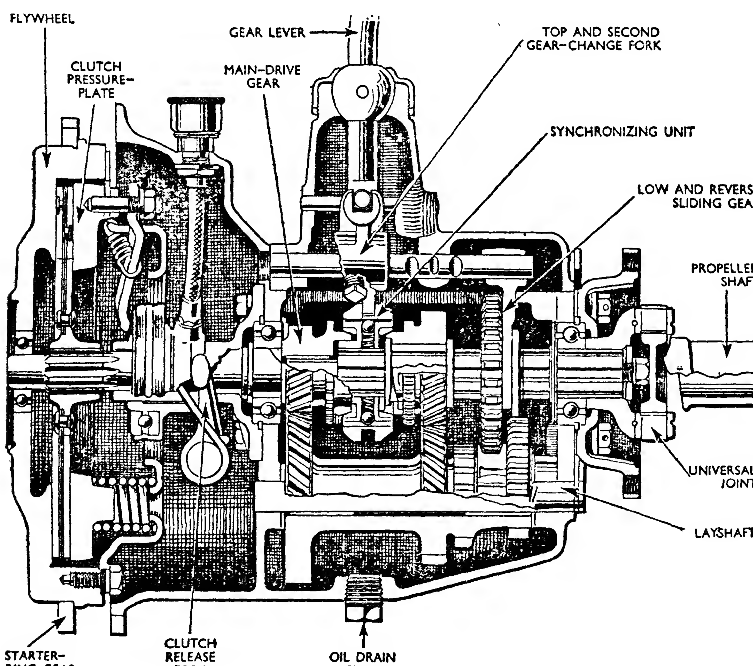
Fig. 4. By the addition of an extra pinion, as shown, reverse gear is obtained.

the driving shaft to the mainshaft. The layshaft revolves idly without transmitting power.

In *first gear* E is moved to a position between E_1 and D_1 (Fig. 1) and is thus disengaged from both. Lever G slides wheel F to engage F_1 and the drive is now A to D, D to D_1, D_1 to layshaft, layshaft to F_1 and thence to F and mainshaft. The reduction in speed is made clear by following the drive from B to A in stages. On the end of A is a pinion D, in mesh with gear-wheel D_1 and as D is smaller than D_1 the layshaft C will rotate at a lower speed than the driving shaft. The first-gear pinion F_1 on the layshaft is driving the gear-wheel F which, again, will rotate at a lower speed than F_1; a further reduction in speed is thus obtained. As the mainshaft B is rotated by F it follows that a double reduction of gearing takes place when the first-gear combination is in operation.

To obtain a *reverse gear* an additional pinion is introduced between the wheels on the layshaft and the mainshaft as illustrated in Fig. 4. To engage reverse gear, the lever G slides the wheel F along the mainshaft to engage reverse pinion R. The turning effort from the driving shaft to the layshaft is carried out as for first and second gears, but the new pinion R_1 on the layshaft, being in constant mesh with R, transmits power to F causing it to rotate in the reverse direction, with the result that the driving shaft rotates in one direction, and the mainshaft in the other.

The position of the selector and wheels F and E when in neutral gear is shown in Fig. 5. These wheels are disengaged from all corresponding



SYNCHROMESH GEARBOX AND CLUTCH

Fig. 6. Sectional diagram showing main constructional details of a three-speed synchromesh gearbox and clutch assembly as fitted to a present-day Ford motor car.

gears on the layshaft and the dog clutch is also disengaged. The driving shaft is thus free to rotate the layshaft without applying any turning effort to the mainshaft.

The selectors G and H are actuated by the gear lever which, in most cases, is situated on the gearbox and shaped to position. A modern gearbox and clutch assembly as fitted to a Ford car is shown in Fig. 6. See SYNCHROMESH GEARS.

GEAR-CUTTING. The process of cutting gear teeth from a blank disk, as distinct from casting the gear-wheel in a mould. There are three principal methods: (1) machining with cutters which are designed to form

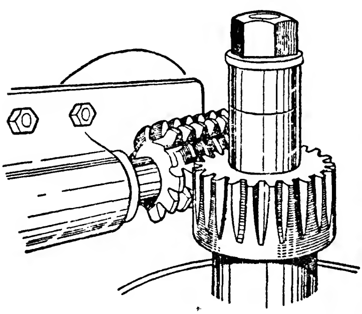


Fig. 1. What is known as the hobbing process is a very accurate method of gear-cutting. Above diagram shows a hob being used to cut a spur gear.

the teeth by copying the profile of the cutters used; (2) generating the teeth by providing suitable rotary and/or reciprocating movements to form the curves of the tooth profiles; and (3) production of gear teeth by master gear-wheels or formers, which are virtually templates governing the travel of the cutter and hence the gear-tooth profile. The last process is principally confined to gears of large dimensions. In carrying out these processes the gear teeth may be machined by a variety of methods:

(a) Cutters corresponding to the intervening spaces between successive teeth of the finished gear-wheel may be used to form the teeth by milling;

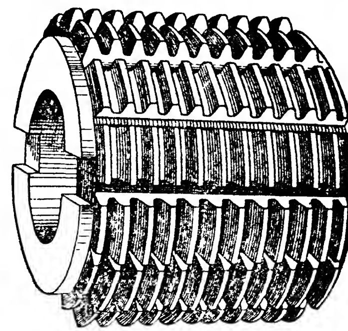


Fig. 2. Hobs may be used to cut spur or helical gears by setting up the machine in the appropriate manner.

(b) A hob, shown in Figs. 1 and 2, may be used to generate the profiles, being equivalent to a rack in the same plane as the gear axis;

(c) Both cutter and blank may be rotated together whilst a circular

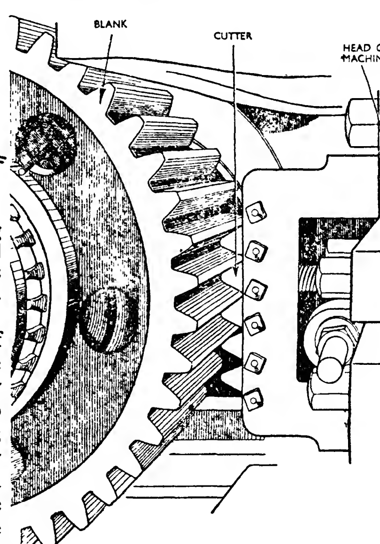


Fig. 3. Planing a spur gear by the Sunderland rack-generating process.

cutter with teeth of the desired shape performs the cutting on the blank;

(d) A former may be used to guide the tool of a planer making a

succession of cuts laterally across the tooth;

(e) A tool, which is a copy either of a single rack tooth or of a section of a rack, may be used to generate the profile of the teeth (Fig. 3). In the former, the tool moves laterally on completing each stroke, and the blank is given an "indexing" rotary movement which ensures correct meshing; in the latter, the tool, shaped to correspond to a short section of the rack, engages with the blank as the latter is rotated relatively to the cutter;

(f) A tool of the same profile as the spaces between the teeth may be used for planing the teeth on the blank.

When high precision is needed, gear-finishing machines are used; a lapping process is frequently carried out on gears which subsequently undergo heat treatment. Grinding is another widely used method of imparting a final surface finish to gear teeth.

GEAR-WHEEL. A toothed wheel used to transmit motion from one shaft to another. There are three general types: spur gears, helical gears and double helical gears. *Spur* gears (Fig. 1) are in the shape of a drum with teeth cut straight across the face parallel to the centre of the gear; they are used when the two shafts are parallel. *Helical* gears have teeth cut at an angle. Owing to their tendency to push each other out of engagement thrust bearings are used. *Double helical* gears (Fig. 2) are frequently used as constant-mesh wheels in gearboxes. See HELICAL GEARS and SPUR GEAR.

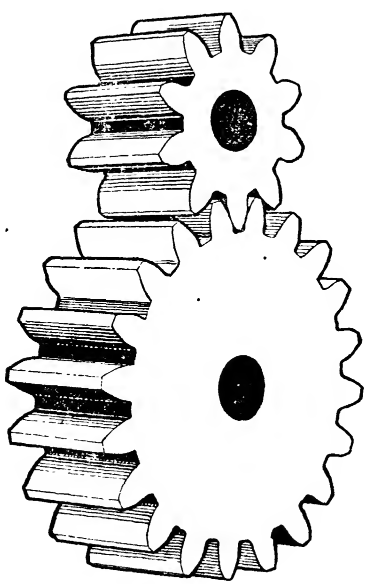


Fig. 1. Straight-tooth spur gears, with teeth parallel to centre line.

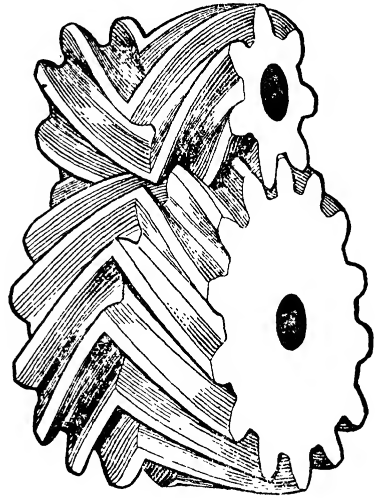


Fig. 2. When double-helical gears are used, the end thrust on one half of each gear balances that of the other.

GEL. Colloids (q.v.), such as gelatin, which partially coagulate to form a mass of filaments that enclose the liquid associated with them, making a pseudo-solid or jelly.

Gels vary very much in properties; some seem to be solid when they really contain only about 1 per cent of solid matter. Some gels become liquid on warming, e.g. gelatin.

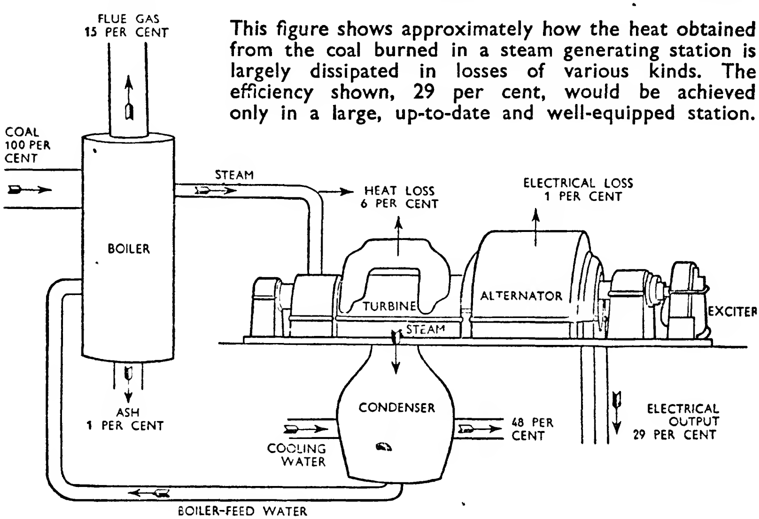
GELATIN. A refined type of glue obtained by stewing animal or vegetable tissue. It is used by painters for making a transparent size for extension upon distemper-printed paperhangings before varnishing with an oil

varnish. It is also used as a fixative for gold leaf in water gilding. See GILDING, GOLD LEAF and ISINGLASS.

GELATION, see CURDLING OF PAINT.

GELS, see COLLOIDS (Chemistry).

GENERATING STATION. A generating station might be defined as a place where as much as possible of the energy stored in a fuel, or in water in an elevated position, is converted into the electrical form. The amount of the available energy which can be converted to the final form is quite small. It varies from 20 to 30 per cent in a steam power station burning coal, so that about 1¼ lb. of coal are used for each unit generated. The way in which the losses are distributed is illustrated, with approximate percentages, in the accompanying diagram.



This figure shows approximately how the heat obtained from the coal burned in a steam generating station is largely dissipated in losses of various kinds. The efficiency shown, 29 per cent, would be achieved only in a large, up-to-date and well-equipped station.

The process of conversion starts with the burning of the coal to heat the boiler, where steam is produced at as high a temperature and pressure as is practicable. The steam is then conveyed to turbines which drive the electric generators. When it leaves the turbines, the steam goes to the condensers to be converted back into water and it is then fed back to the boilers ready to be used again.

That, of course, is the bare outline of the process. In order to achieve as high an efficiency as possible, every effort is made to extract heat from the boiler smoke and condenser cooling water, the air for burning the coal is preheated, and so on, so that a modern steam power station is quite a complicated affair.

To give an idea of the quantities involved, the figures for a particular station may be of interest. Coal is used at the rate of 100 tons per hour to boil 650 tons of water per hour. The steam is superheated to about 900 deg. F. To condense the steam nearly 3 million gallons of water are needed every hour and the total output of the station is about 250 MW. The power required by the auxiliary apparatus in the power station itself amounts to about 5,000 kW.

The cost of building and equipping the station amounts to about £14 per kW, and the cost of generation is about ⅜ of a penny per unit. All these figures are rounded-off and apply to large stations. Smaller stations do not operate so efficiently or so cheaply.

Internal-combustion engines have the advantage that they can be started-up and put on load much more quickly than is possible with a steam turbine. Moreover, the losses are

smaller when the station, or parts of it, are standing by. For smaller outputs, a diesel-driven station may prove to be more economical, but much depends on the relative fuel-costs at the site, the load factor (q.v.) and other considerations.

Hydro-electric stations are an attractive proposition where ample water power is available. The cost of the water is nothing, so that generating costs are low. On the other hand, the cost of construction is much higher than that of a steam station, owing largely to the extensive civil engineering works required. The ratio may be from 3 to 8 according to the cost of these works.

Another factor to be considered is that supplies of water and demand for power do not often occur in the same place, whereas steam stations may usually be erected near the seat of the load. The cost of transmission has, therefore, to be added to the cost of generation in fixing the price at which electricity can be sold.

GENERATOR. An electrical machine used to convert mechanical power into electrical power. See ALTERNATOR and D.C. GENERATOR.

GEODETIC STRUCTURE. A type of construction developed for aircraft and incorporated in the Vickers-Wellesley and Wellington Bombers. The principle on which it is based can be illustrated as follows:- Consider a square framework which is braced by two curved diagonal members. Loads applied at two opposite corners of the square as shown would tend to deform the shape of the square and to straighten the diagonal member A and bow the other still further. If, however, the diagonal members are fastened together at their intersection they offer

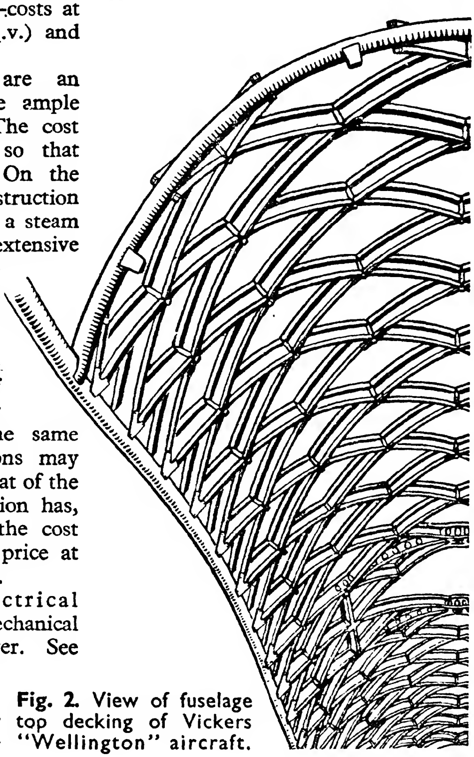


Fig. 2. View of fuselage top decking of Vickers "Wellington" aircraft.

a much greater resistance to deformation, and the whole structure is thereby strengthened. This is shown diagramatically in Fig. 1. Geodetic aircraft structures (see Fig. 2) are built up of panels which have rows of curved stiffeners at right-angles to each other, and these stiffeners are secured to one another at every intersection.

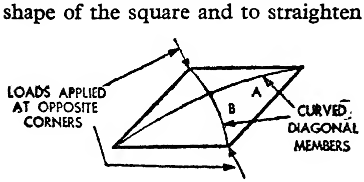


Fig. 1. Diagram showing principle of geodetic construction in aircraft.

GEOMETRIC PITCH. The distance which a propeller would advance in one revolution, if it were screwed forward through a solid medium. If θ is the blade angle at a point whose distance from the axis is r, then the geometric pitch is $2\pi r \tan \theta$. In some cases θ does not vary along the blade in such a way as to maintain

a constant value of $2\pi r \tan \theta$, and the geometric pitch is then taken as the value of $2\pi r \tan \theta$ where $r = \frac{2}{3}$ of the full radius of the propeller.

GIB. A special form of wedge, often used in conjunction with a cotter (q.v.) intended to keep together two sliding portions of an engine or machine. Gibs are also known as adjusting or take-up strips. Their chief purposes are to prevent or reduce slackness ("slogger") between the sliding surfaces and to provide compensation for any wear that may arise in service.

There are three principal varieties of gib, grouped according to the means by which adjustment is effected. In the first, the gibs are adjusted by the action of screws set perpendicularly to the direction of the slide; in the second, a wedging effect between the slide and the slide way is set up by using angular gibs which are thrust sideways to give the desired pressure; in the third the gibs are formed with tapering edges which give the required wedging action when the gib is driven home.

GIB AND COTTER, see JOINTS.

GIG-STICK. A radius rod, used in the process of running plaster arches to give the required curve to the arch.

GILBERT. A unit of magnetomotive force, which is related to the ampere-turn as follows: one ampere-turn equals $\frac{4\pi}{10}$, that is 1·257 gilbert. See AMPERE-TURN and MAGNETOMOTIVE FORCE.

GILDING. The application of gold leaf (q.v.) to a surface or moulding; it requires a mordant, or fixative, generally termed "size", which may be a slow-drying oil, a quick-drying varnish or a water-soluble jelly. The work executed upon these fixatives is referred to as *oil* gilding, *japan* gilding or *water* gilding respectively.

For oil gilding the size is prepared from old and partially oxidized refined linseed oil, into which is ground a little golden ochre and acetate of lead; ease in working is obtained by the addition of a little boiled linseed oil. When extended as a film it should be sufficiently dry in 24 hours for holding the gold and should retain that condition for at least 48 hours.

The ground to receive the size is prepared by painting in oil paint and must have a dull finish, be free from brush marks and have been recently applied. This is cut down with fine abrasive paper and dusted; the size is laid with fairly stiff brushes as an even film, care being taken that the material does not accumulate in the hollows. During the twenty-four hours it is drying, the surface must be protected from dust and draughts.

When the surface is sufficiently dry for gilding the gold leaf to be used is turned out of its protecting booklet on to a pad or cushion, seen in the illustration; this is a rectangular board 9 in. by 6 in. padded and covered with chamois leather, one end and part of each side being surrounded by a parchment shield with, underneath, a thumb loop conveniently placed for holding the board horizontally upon the side and index finger of the left hand. From the gold within the shield one leaf at a time is taken up with the gilding knife and laid on the fore part of the pad; a puff of breath in its centre is sufficient to extend the leaf out flat so that it may be cut to the required size with the knife. The gold is picked up with a *tip*, (a thin, flat long-haired brush) also illustrated, and placed upon the goldsize.

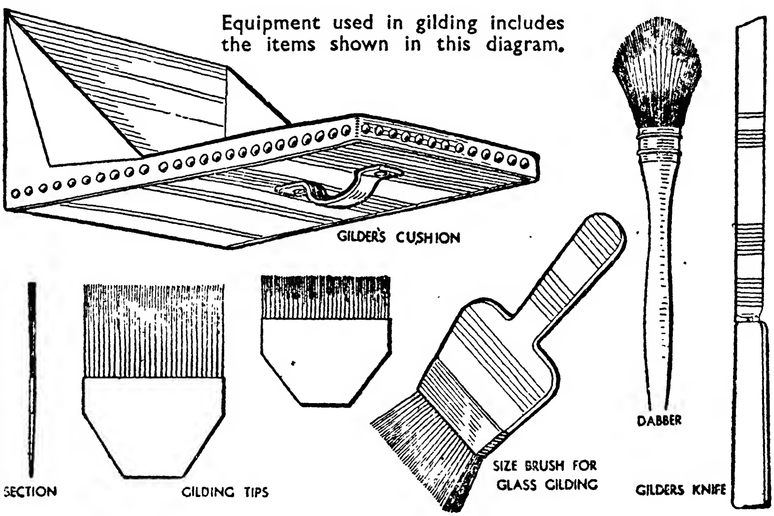
Points to note are: gild all the tops first, cut the gold small enough to lie down flat when approaching an internal angle, and do not be afraid of a little overlap. When the whole is covered by the leaf gold, press into contact with a pad of cotton wool or a soft-haired brush called a *dabber*; after two hours wash with clean water. To keep the tip clean, pass the hairs across the cheek or the hair occasionally. Oil gilding is the best medium for large work and for all surfaces broken by modelling or cast enrichments.

Japan goldsize is a type of quick-drying oil varnish made from the

softer gums or resins; with ageing it does not relinquish its hold upon the applied gold; varnishes made as finishes are unsatisfactory for gilding upon. Japan goldsize may be obtained to assume a gilding tack in from half-an-hour to four hours. Quick size is used mainly for small lettering and lining; a little lemon chrome ground in oil is added to give definition.

All varnished or oil-painted surfaces upon which gold lettering is applied should be first coated with a size, made from the white of one egg beaten up in one pint of cold water, extended upon the surface with a soft-bristled brush, and the brush markings removed by softening with a badger brush; when dry this is rubbed over with a soft cloth pad containing whiting, the process being termed *pouncing*. For gilding upon quick size the gold leaf is attached to waxed tissue paper and is known as *transfer* gold leaf. When the size has assumed the gilding tack, the gold leaf is placed upon its surface and pressed into contact with the thumb or a small wad of cotton wool. This is a very economical way of gilding, as the gold is removed from the paper backing only where it is placed upon the sized portion and pressed into contact. When the whole has been gilded, the work is immediately washed with clean cold water to remove the egg size from the varnished surface; if this is allowed to remain longer than necessary the gloss of the varnish will be impaired and, with ageing, may develop cracks in the surface.

With painters, water gilding is mainly confined to gilding upon glass. All this type of work is executed in reverse upon the back surface of the glass, which necessitates the use of an exceedingly clear and clean form of size. A pinch of shredded isinglass, placed in a pint of cold water in a clean pan and brought to boiling point, will provide the ideal adhesive.



Equipment used in gilding includes the items shown in this diagram.

The glass is thoroughly cleansed with whiting and water and the letters, or ornament, set out on the front side. The plate of glass is placed upon an easel and the back and edges cleaned. The gilding cushion, filled with gold leaf, together with the knife, tips, hot size and a soft-haired brush are assembled.

A section of the plate is laid-in with the hot size; while this is still flowing wet, the gold is cut to the required size and placed into position with the tip. The wet surface draws the gold from the tip and spreads it out flat;

the laying is continued until the wetted section is completed. The next section is wetted and the operations continued.

The main points to note are: work from left to right, lay the size in small patches from bottom to top, keep the wet edge "alive", do not turn back and try to make good any sections that may have been missed. When dry, any unattached gold is taken off with a piece of open cotton wool, then, with a pad of cotton wool, the gold adhering to the glass is polished.

The size is then again heated and the whole plate again coated; any missed patches are made good with gold on the wet size. When again dry the gold is burnished once more with a pad of cotton wool.

For small lettering and cheap work one coat of gold is generally considered sufficient, but for large letters and areas such as backgrounds a second coating is necessary. For backing-up, a thinner type of gold leaf is generally used. Its application and subsequent treatment follow that indicated for the first coating. When all is dry and burnished the part of the gold required to form the letters or ornaments is backed up with a coat of black japan. When the black japan is dry the surplus gold and the size on the remainder of the glass are removed with a damp cotton pad and whiting.

The plate is now ready to receive the paint for outlining, shading and background. Where gold letters are left as isolated units the coat of black japan is followed by one of black oil paint extended a little beyond the letter to form an outline, followed by a coating of an elastic varnish which is also allowed to form an extra outline. This protects the work from mechanical damage liable to occur with the cleaning of windows.

GLASSPAPER, see SANDPAPER.

GLAZING (Building). The operation of fastening glass in wood or metal frames by means of putty or beading; the latter may be of either wood or metal. The glass is secured in rebates on a bed of putty with a putty or bead fillet to cover the joint between the frame and the glass. The glass sheets should be cut to a loose fit and the rebate should be about ⅜in. deep.

GLAZING (Painting). The process of extending a wash of transparent colour, in graining and marbling, in such a manner that the method of its extension is not evident. It is generally employed to modify the hue or tone value of an existing ground colour.

GLIDE (Aero. Engineering). An inclined descending flight of an aeroplane with the engine shut-off or throttled back. As the machine descends, the work done by gravity overcomes the air drag. The best gliding angle of an aircraft may vary from about 1 in 10 to 1 in 20; i.e. for every mile travelled horizontally the height lost would be between 528 feet and 264 feet, depending on the efficiency of the design.

GLIDER. A flying machine with no engine. Prolonged flights are possible only if suitable conditions prevail, such as when there are currents of air rising at a rate equal to, or greater than, the rate of descent of the glider. These rising currents of air may be found where a horizontal wind is deflected upwards by a hill, or under cumulus clouds. Rising currents under clouds are called thermal currents.

Gliding was an established sport amongst a limited number of enthusiasts before 1939 and many types of single-seat machines were in common use, from the somewhat crude but robust primary gliders for initial training to the beautifully streamlined sailplanes. Sailplanes are the most efficient types and have made flights of some hundreds of miles. There were also a few two-seater types.

During the Second World War many very large troop- and cargo-carrying gliders were used with considerable success. The combination of a transport aircraft and towed glider can carry a greater load at a somewhat lower speed than the transport aircraft could carry alone.

GLOBE COCK. A tap or valve with the body and outlet in the form of a globe, usually fitted to baths. The inlet is at the back, for connexion to a bent union, the thread of which screws over the threaded inlet through the thickness of the bath and so secures the cock. The construction is similar to that of a stop cock (q.v.).

GLOSS INK. A modern printing ink consisting of a synthetic resin base together with drying oils to give maximum reflexion. These inks dry quickly and hard; they must not penetrate the paper, which should be smooth and hard surfaced, or hard sized. Coated art or chrome papers give the best results. Owing to lack of penetration the ink coverage is good. Gloss inks allow the character of the paper to be retained in the unprinted parts as against an all-over varnish after printing. A similar effect can be obtained by making a normal printing followed by gloss varnishing from the same forms.

The use of anti-set-off sprayer (q.v.) is essential for best results; alternatively work should be laid out in small piles, care being taken to avoid rubbing, which impairs the gloss. As the ink sets, the sheets should be carefully shaken up to prevent sticking.

Gloss inks are made both for letterpress and lithographic printing. They flow more freely than ordinary inks; their working properties are good, but the colour range is limited. Owing to rapid drying, it is advisable to make-ready with ordinary inks and then to wash-up and proceed with the gloss printing without delay.

GLOSS PAINT. Oil paint containing varnish or a reinforced or partially oxidized drying oil. These paints have a very extensive range of colour.

GLOW DISCHARGE. A luminous electrical discharge in a gaseous conductor.

GLUCINUM (Gl). The name formerly used to designate the element now called beryllium (q.v.).

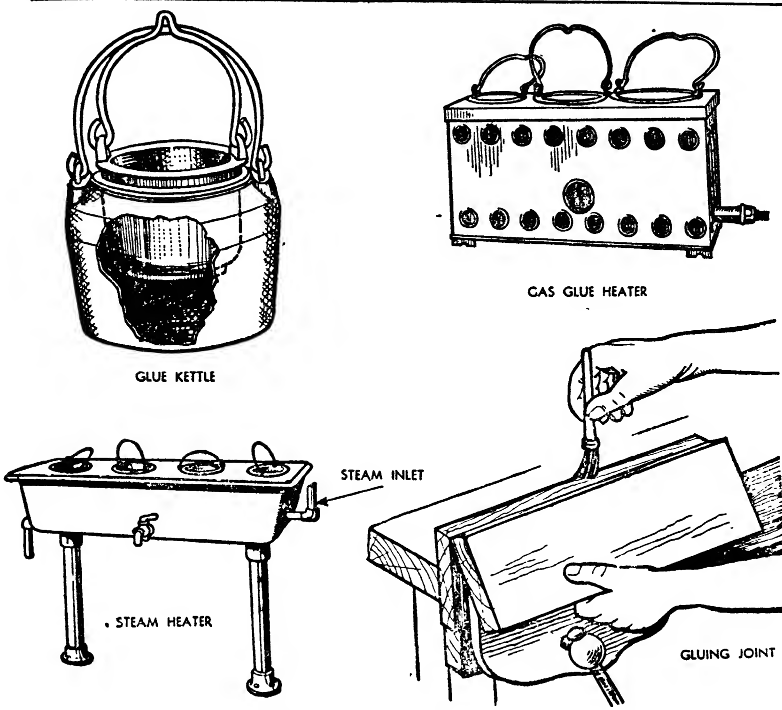
GLUCOSE ($C_6H_{12}O_6$). A sugar typical of the hexose class containing six carbon atoms. It is present in many fruit juices and in the blood of mammals, and may be prepared from cellulose, starch and cane sugar. It exists in several forms, some of which are stable only in solution. See CARBOHYDRATES.

GLUE. Originally, a hard, brittle gelatin obtained by boiling animal hides and hoofs and the skins and bones of fish; only partly soluble in cold water, but readily soluble by the application of heat; the term is now in more general use to describe the vast range of plastics and cements.

Glue is also used by painters in a dilute form, known as "size", as a fixing agent for distemper painting; for correcting the excessive absorption of porous surface; for the establishment of an oil-resisting film upon wall-papers and distemper work before varnishing with an oil varnish; and as an emulsifying agent in the production of the mediums used in some washable distempers.

The glue used in woodwork, except in mass-production, is still chiefly of animal origin. It is generally sold in cakes which are broken into small pieces and soaked in cold water for at least 12 hours before being heated in a water-jacketed vessel to between 120 and 150 deg. F. Under-heating prevents penetration of the wood, and over-heating destroys the efficiency of the glue.

To obtain good results, the glue must be hot and of such consistency that it will drip off the brush. As soon as glue is applied the joint is rubbed or cramped until the surplus glue is squeezed out. Dry wood and a warm atmosphere are necessary. *Powdered* glue is similar to cake glue but is ground into powder and requires soaking for only about one hour. *Liquid* glue has the advantage that it is always ready for use in temperatures over 60 deg. F. It is not so good as the best cake glue, but is more uniform in quality. *Casein* glues are made from dextrines or caseins, and are sold in powder form. They should be mixed with cold water and used the same day. They set like cement and are waterproof, fireproof and resistant to



HEATING AND APPLYING GLUE

There is a variety of appliances available to assist in gluing. Above are shown three kinds of equipment for heating the glue before its application. The method of applying glue to a joint before bringing the two members together is also shown.

moulds and bacteria; they are thus invaluable in the tropics.

Plastics or Resin glues, in recent years, have revolutionized the methods of gluing for plywood, aircraft and other mass-produced woodwork. These adhesives are divided into several groups, and may be applied in either liquid or dry form. The thermo-hardening group, such as phenol-, urea-, and soya-formaldehydes, are permanent once they are cured, or set, but the thermo-plastic group, such as cellulose derivatives and acryl- and vinyl-polymers, can be made plastic again on reheating. Other groups are casein plastics and natural resin adhesives. The uses of these groups are almost unlimited, but they require expensive equipment and expert control. They are strong, waterproof and fireproof, and the setting time can be regulated by the addition of hardeners.

Urea-formaldehyde thermo-setting resin, known as *plaskon*, is extensively used. It is applied in liquid form, usually by machine spreaders, either as "hot press" or "cold press" resin. The former requires "cooking", or moulding in an autoclave. The prepared work is clamped and placed in a watertight rubber bag, and run into the autoclave.

Hot water and compressed air are admitted into the autoclave as required, to set the bonding agent and provide the necessary pressure. This method allows for a time interval of two or three days for assembling the laminated structures, which may be the fuselage of an aeroplane, a boat,

or any other form of monocoque construction.

Cold-press resins do not require heat, but allow an interval of only 15 minutes or so before the application of the required pressure. Dry resins are applied in powder form, or as a cellophane-like sheet placed between the wood laminations. When the prepared work is cramped and placed in a heated press, the resin fuses and makes a permanent joint. Methods of curing by electric current are being rapidly developed.

GLYCERINE. A compound of the constitution $CH_2OH.CHOH.CH_2OH$ also known as glycerin and glycerol. A colourless, viscous, sweet liquid, boiling at 290 deg. C., it is miscible with water and alcohol. It occurs in combination with various fatty acids in all animal and vegetable oils and fats, and is obtained in large amounts during the manufacture of soap.

Soap is made by treating molten fats with a hot solution of caustic soda, which break up the fats to form a mixture of sodium salts of the fatty acids and a solution of glycerine in water. The soap is removed and the liquor is distilled to yield first, commercial glycerine, and finally, pure glycerine.

Glycerine is used in considerable quantities in medicine, and in much larger quantities in the manufacture of the explosives nitroglycerine and dynamite, and synthetic plastic resins.

GLYPTAL SYNTHETIC RESINS. Resins formed by treating glycerine, glycol and other substances with organic acids such as tartaric acid, citric acid or phthalic acid. The glycerine resins are mixed or combined with natural or synthetic resins to make finishing varnishes used in considerable quantities. They are also known as alkyd resins.

GOING, see STAIRS.

GOLD (Au). Atomic no. 79; atomic wt. 197·2; a bright yellow metal, very ductile; it may be beaten into leaves 0·00009 mm. thick; density 19·43; m.p. 1063 deg. C., b.p. 2610 deg. C. It forms two classes of compounds: aurous compounds, e.g., aurous chloride, AuCl; and auric compounds, e.g. auric hydroxide, $Au(OH)_3$.

Gold does not readily corrode, and as it is found in the metallic state, it was one of the first metals known to mankind. It occurs also in auriferous pyrites. The finally crushed rock containing gold is treated with a solution of potassium cyanide which dissolves the gold. This is recovered by adding metallic zinc to the solution to precipitate the gold, which is then fused to purify further.

Pure gold is too soft to be used for coinage or ornaments, and for these purposes it is alloyed with silver or copper, or both. In Britain, the purity of gold is often expressed by carats, pure gold being 24-carat, and 22-carat gold containing 22/24 of gold. Potassium aurocyanide, $KAu(CN)_2$, is used in electroplating. Purple of Cassius is a colloidal form of tin oxide containing gold; it is made by precipitating gold chloride with tin chlorides and is used for making ruby-coloured glass.

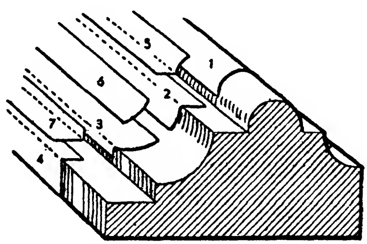
GOLD LEAF. Gold beaten out into thin leaves, or sheets, sometimes no more than one ten-thousandth part of a millimetre in thickness. It varies in colour from pale yellow to a deep reddish tint, the change being obtained by admixture to a greater or lesser degree with other materials. It may be obtained in various thicknesses; cheap gold, being excessively thin, is difficult to handle and lacks the lustre of leaves having a more substantial character.

The leaf is made in two qualities (1) from pure gold, and (2) with a slight amount of copper or silver alloy. The metal is melted in a crucible and cast in slabs 6 in. × 1 in. × $\frac{1}{8}$ in. This is then rolled with many passes between steel rollers, until it becomes a ribbon 1/1000 in. in thickness. The gold ribbon is then cut into 1 in. squares which are placed in between 200 sheets of fine vellum 4 in. square and hammered by hand until the gold is beaten-out to the size of the vellum. Without being touched by hand, the gold

leaves are then removed, quartered and placed between 800 strong skins of a shodder measuring 4½ in. square.

The shodder is carefully beaten until the gold spreads to the size of the skins. Again, the gold leaf is quartered and placed between the skins of a mould; these gold beaters' skins are 5¼ in. square and are so thin that 1000 of them measure less than one inch in thickness. The beating of this mould is the really critical process and determines the quality of the finished leaf. After beating for some hours to obtain the required size and thinness, the gossamer-like leaf is then cut singly to the standard size, and inserted in books containing 25 leaves.

Gold leaf is used in a number of trades: gilding, as is shown below;

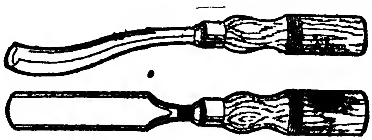


Gold leaf is applied to surface of a moulding in the order shown above.

painting; signwriting; bookbinding etc.

On account of the high degree of mechanization in modern bookbinding, gold foil is also provided in increasing quantities for use on automatic stamping machines. The foil is backed with cellophane and sized to ensure adhesion to the various surfaces to which it is applied. Marked economy is effected by this method, as the unused foil remains on the cellophane base and is re-wound.

GOUGE. A chisel-type tool with a curved cutting edge. There are many sizes and different curvatures, and they may be ground on the outside or on the inside. The latter are used for paring and will not stand heavy work. Gouges may be curved in their length. V-shaped tools are usually



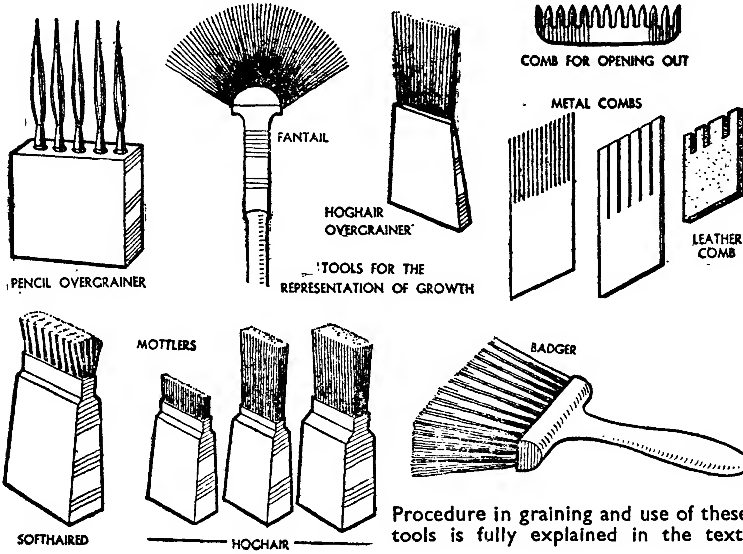
Bent gouge (top) and firmer gouge (bottom) as used by the carpenter.

called *parting* tools. They are used for carving and for wreathed handrails etc.

GRAINING. The process of imitating in paint the natural characteristic markings of timber. This is done by laying a ground, representing the colour and tone of the lightest portion of the wood, which, when dry, is followed by a transparent glaze evenly extended over the whole surface; this is worked upon while wet by taking from, or adding to, its density in imitation of the natural markings. The glaze is always laid on and brushed out evenly in the direction in which the main markings of the grain are to run. Good graining demonstrates considerable restraint in tone contrasts and the representation of normal growth rather than the exploitation of freaks.

All timbers show the means by which the trees increased their girth; in quick-growing timbers this is somewhat pronounced and forms the main pattern, as in pitch pine, ash etc. In timbers which grow more slowly it may be restrained, and the pattern will depend upon the interweaving of the transverse fibres and the undulating action of growth. The study of actual timber is essential, not from small, picked samples, but as selected and used by the carpenter in the construction of buildings, and of the cabinet maker in the construction of furniture.

Brush graining attempts nothing more than the characteristic colour, texture and construction. The glaze is laid, stippled with the ends of the bristles followed by dragging, or flogging, with the sides of the bristles of a clean brush. The glaze may be in either oil or water medium. In some timbers several films are required and in such cases an oil film can be used



Procedure in graining and use of these tools is fully explained in the text.

upon a previously applied water-medium film without any intermediate fixing.

For indicating growth and texture various tools as illustrated are in general use: *combs*—made from metal, leather and rubber; *brushes*—sash tools, fitches, fantails, bristles and pencil overgrainers and pencils. For indicating undulation, *mottlers* and *cutters*, both hoghair and sable, in many widths, lengths and thicknesses, together with hoghair and badger *softeners*, are required. All mottling is best executed in a water medium.

Where it is to be executed in oil the overlapping effect or feather-edge marking required for many timbers is obtained by allowing the glaze to set and then drawing the pattern with a pencil, using colour a little darker than the glaze for darker marks; for lighter marks turpentine alone is used and is drawn out in one direction with a hoghair softener. If a water medium is being used, allow the glaze to dry and employ the same method, replacing the turpentine with water and using a badger softener.

GRAIN STRUCTURE. The appearance of the grains (crystals) in a base metal or alloy. A section of about ½-in. square or diameter is cut and one surface carefully polished, using successively finer grades of emery, followed by polishing powder on a rotating disk covered with wet "selvyt" cloth. The prepared surface is immersed for a few seconds in an etching solution, then washed and dried. The different crystals are attacked selectively, the outline of the grain boundaries being revealed.

The most satisfactory section for sheet metal is one cut parallel to an edge in the direction of rolling (Fig. 1). Examination of this section shows the grain structure through the entire thickness of the sheet, as well as

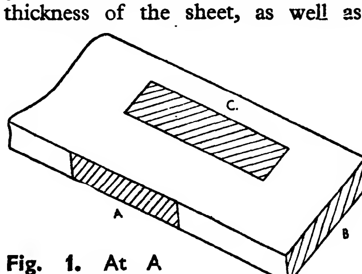


Fig. 1. At A above is shown the most satisfactory choice of a section of specimen sheet for micro-examination. Sections such as those indicated at B and C are not recommended.

internal defects and the effects of rolling. Preparation of such thin sections is facilitated by clamping several together in a suitable mount. Large grains are often visible to the eye, or under low magnification. The structure of fine-grained material is examined under the microscope; a pure metal or an alloy of the solid-solution type (cupro-nickel or cartridge brass) consists of irregular polygonal grains (Fig. 2). Steel and other alloys show various constituents according to their composition and heat treatment.

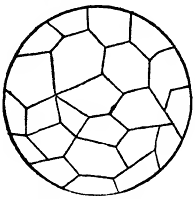


Fig. 2. Irregular polygonal grains in a pure metal or solid solution.

GRAM EQUIVALENT. The equivalent weight of a substance expressed in grams; thus, the equivalent weight of sulphuric acid is 49, therefore the gram equivalent is 49 grams. Similarly a gram atom and a gram molecule are the atomic and molecular weights expressed in grams.

GRAMOPHONE PICK-UP. A device enabling gramophone records to be reproduced through an electric amplifier by converting the mechanical vibrations of a gramophone needle into corresponding electrical variations. The construction of the most familiar type of pick-up is illustrated; a gramophone needle is clamped in a small iron armature located between four magnetic pole pieces and is pivoted at the lower end and held centrally between the pole pieces at the upper end by means of a suitable piece of soft rubber. Surrounding, but not touching, the armature is a fine-wire coil.

The needle, following the waves in the record groove, causes the armature to swing from side to side in the magnetic field, varying the flux in the armature and producing corresponding e.m.f.s across the ends of the coil. These voltages are passed on to a valve amplifier. Since the moving parts must vibrate at frequencies from as low as 50 cycles per second to at least as high as 5,000 cycles per second, it is clear that they must be as light and free as possible, the rubber damping being sufficient only to prevent mechanical resonance.

Another popular modern type is the piezo-electric (q.v.) pick-up which utilizes the properties of the piezo-electric crystal. The output voltage is much the same as in the conventional high-impedance electro-magnetic type, but certain precautions have to be taken: for example, it should be borne in mind that such a device does not provide a D.C. path, and special arrangements for providing an amplifier valve with grid bias have to be made.

GRAPHITE. A form of carbon, also called *plumbago* and *black lead.* When used as a pigment for paint it is a fine powder in the form of microscopic hexagonal crystalline plates similar to bronze, and is leaden or grey in colour and slippery to the touch.

With a linseed-oil medium it is made into a paint for the protection of ironwork and has long been used by the housewife for this purpose. In the process of its extension as a film by brushing, all the plates are laid flat and form an impenetrable and compact layer.

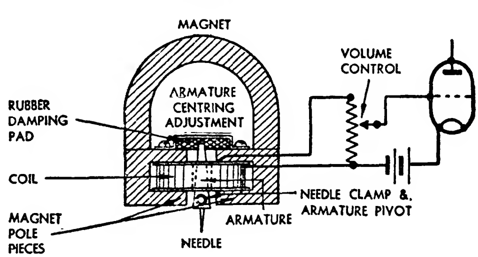
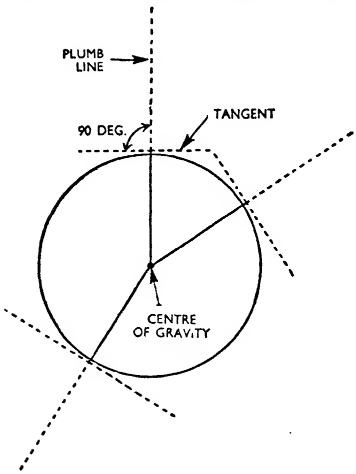


Diagram showing the construction of a popular type of electro-magnetic gramophone pick-up.

GRAVITY. The attraction exerted by any mass in space upon any other mass; i.e. the pull exerted by the

earth on the moon, by the sun on the earth, or by one body on any other body in the universe. Newton's law



Since lines of gravitational force radiate from the centre of the earth, a plumb line always makes a right-angle with a tangent at that point.

states that "any two particles of matter attract one another with a force directly proportional to the product of their masses, and inversely proportional to the square of the distance between them;" i.e., the power of attraction between two bodies depends on their respective weights and distance apart. Newton's law gives the equation:—

$$G=\frac{M_1\, M_2}{D^2}$$

where G is the gravitational pull, M_1 and M_2 the masses, and D the distance between them.

The gravitational pull of a body is assumed to act from the centre of gravity of that body, which, in the case of a sphere or spheroid, is also the circumferential or geometric centre. The illustration shows how the lines of gravitational force radiate from the centre of the earth and form right-angles with the tangents at any point on the circumference; i.e. the gravitational pull at the earth's surface acts in the direction assumed by a plumb line—the true vertical. See CENTRE OF GRAVITY.

GRAVITY DIE-CASTING, see DIE CASTING.

GREASE CUP. A device in two parts, forming body and cup, which is used for lubricating certain kinds of mechanism. The body screws into the part to be lubricated and is fitted with a second thread on which the inverted cup is screwed. The cup is filled with grease and, as it is screwed down, it forces the grease through a hole in the body of the cup into the bearing. Grease cups are usually fitted to dynamos, water pumps, spring links, steering etc.

GREASE GUN. A device for forcing grease between bearing surfaces such as spring shackles, brake and clutch mechanism. of a motor vehicle. It is made up of a cylindfical barrel and plunger. The barrel is filled with grease and, as the plunger is pushed in, the grease is forced out through a tube on the end of which is a nozzle. The nozzle is designed to fit on a nipple screwed into the member to be greased and the full pressure of the gun is applied to the part required.

GREENS (Painting). The main greens used in oil painting are *Brunswick* or *chrome* greens, and may consist of Prussian or similar blue mixed with a lead chromate pigment and an extender. In such a physical mixture of two prefabricated colours which differ materially in weight there is a tendency for the colours to separate when ground with linseed oil into a thin paste, the heavier pigment chrome sinking to the bottom of the container and thus destroying its uniformity of hue. To prevent this, solutions of the materials from which Prussian blue and chrome are made are run together and precipitated in one operation. The greens vary in colour from a pale yellowish hue to a deep blue-green; in contact with sulphur fumes they darken in colour, and in contact with free lime their colour is destroyed.

Lime green, a bright bluish-green similar in composition to Ultramarine blue, is a compound of sodium,

aluminium, silicon, sulphur and oxygen; it is specially made for use with lime, by which its colour is unaffected. In a water medium it has good obscuring power; but ground in oil is practically transparent and has little straining power. *Oxide of chromium*, a rather yellowish, dull green of uniform colour, is used mainly in oil paint for the protection of ironwork. It is permanent under all conditions and has great opacity or obscuring power.

Viridian, emerald oxide of chromium, is a pure, brilliant green. It is practically transparent in an oil medium, permanent, stable and inert. Its use is mainly restricted to the artist's palette.

Bronze greens are mixtures of chromes and black pigments. *Sage* greens are mixtures of ochre and black. *Myrtle* greens are mixtures of blue pigments and ochre.

GREEN-SAND MOULDING. A speedy and economical method of making moulds. The mould is simply rammed with moist sand, which is not dried before pouring the casting; on the contrary, the metal may be poured immediately the mould is rammed. Steam is naturally generated by contact between the moist sand and hot metal, but causes little trouble. On large castings scabs may be formed, but these can be avoided by skin-drying the mould by means of a kettle or gas flame.

The process is cheaper than dry-sand moulding, since the cost of drying is avoided and fewer moulding boxes are required. Both large and small work can be made in green sand, but it is most suited to the simpler types of casting, and probably finds its greatest application in machine and plate pattern-work.

GREY CAST-IRON. A cast-iron for general purposes, containing 2·8 to 4·0 per cent carbon, 1 to 3 per cent silicon, 0·3 to 1·5 per cent phosphorus, 0·05 to 0·15 per cent sulphur and up to 1 per cent manganese. The quality of the iron is largely controlled by the proportion of silicon present, and to a lesser extent by the amount of phosphorus. The dark fracture of grey cast-iron is due to the presence of free graphite, without which the iron would be hard and unmachinable.

Silicon promotes graphitization and should be adjusted in the charge to give a suitable structure in the casting. The exact amount required depends on the thickness of the ruling section of the casting, the proportion decreasing as the section of the casting increases; thus for castings ¼ in. thick as much as 2 to 2·5 per cent silicon may be required, whereas for castings 2 to 3 in. thick only a little over one per cent of silicon is necessary. In general the silicon is so proportioned that the combined carbon content of the casting is 0·7 to 0·9 per cent.

Phosphorus in amounts exceeding 1 per cent is useful in imparting fluidity to the iron for making castings of very light sections, but it

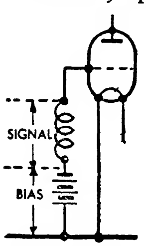
Dia. of Test Bar In.	Transverse Test			Tensile Test		
	Distance Between Supports In.	Medium Breaking Load Lbs.		Gauge Diameter of Test Piece In.	Minimum Ult. Tensile Stress Tons per Sq. In.	
		Grade A	Grade C		Grade A	Grade C
0·6	9	530	420	0·399	12·5	10
0·875	12	1185	960	0·564	12	10
1·2	18	1950	1600	0·798	11	9
1·6	18	4280	3650	1·128	10·5	9
2·1	24	6660	6020	1·596	10	9

tends to make the iron brittle and impairs the strength. For best results, the phosphorus content should never exceed 0·8 per cent and preferably not more than 0·6 per cent.

Two grades of cast-iron are given in British Standard Specification No. B.S. 321, for General Grey-Iron Castings, the test requirements being given in the table on the previous page.

GRID. A framework, usually of lead alloy, which supports the active material on the plates of an electrical accumulator (see LEAD-ACID ACCUMULATOR). In radio engineering the term denotes an electrode, in a valve, situated between the cathode and the anode, which exercises electrostatic control of the electrons. See RADIO VALVE.

GRID BIAS. A voltage, either fixed or variable, applied to the control grid of a radio valve as shown below. In most valve-amplifier circuit arrangements, the grid is biased negatively with respect to the cathode.



Circuit for applying grid bias to radio valve.

There are two main reasons for this. First, the grid should not be allowed to become positive even at the peak of the positive half-cycle of signal voltage or part of the electron stream would flow to the grid and there develop voltages which would interfere with normal operation; secondly, the bias enables the valve to be operated on the linear portion of its characteristic curves, thereby ensuring distortionless operation.

In battery-operated sets, a few small cells are often used to provide this voltage, while in mains-operated receivers and in certain modern battery sets bias is now often automatic. See AUTOMATIC GRID BIAS.

GRID CONTROL. The control of the behaviour of an electrical mercury-arc rectifier, or similar apparatus, by varying the voltage between grid and cathode. See MERCURY-ARC RECTIFIER.

GRID-CONTROLLED RECTIFIER, see THYRATRON.

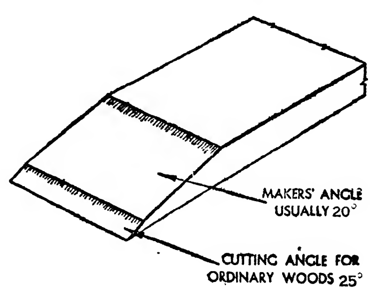
GRID LEAK. A term applied to a resistor, usually of high ohmic value, connecting the grid of a valve to its cathode or source of negative bias.

GRID-LEAK DETECTOR, see LEAKY-GRID DEMODULATION.

GRID SYSTEM, see TRANSMISSION.

GRILLAGE. Horizontal steel sections placed under the stanchion bases, taking the place of footings of a building to enable very heavy concentrated loads to be spread over large areas. The steel sections are placed side by side in one, two, or three tiers, bolted together and attached to the stanchion base, the direction of the sections being at right-angles in adjoining tiers, above or below. The number of tiers depends upon the load and the bearing capacity of the soil. The steel sections are enclosed with at least 4 in. of concrete at the ends, bottoms and sides, and the spaces between the sections are filled with concrete, thus making a solid reinforced concrete block. See COLUMN FOUNDATION.

GRINDING AND SHARPENING (Carpentry). Cutting tools, with certain exceptions such as pocket chisels, are ground at one angle to reduce the main thickness of the blade, and are set, or sharpened, at a steeper angle to bring them to a fine edge. This is done to obtain a



Sharpening angle of chisels and plane-irons may be varied according to hardness of wood worked on.

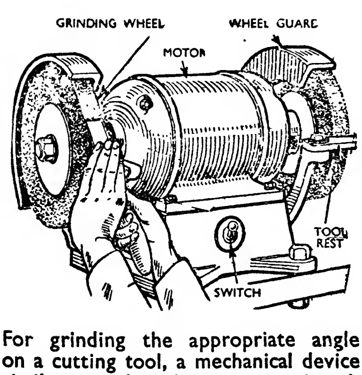
thickness of metal immediately behind the edge for strength or support, and, at the same time, to keep the blade thin enough for easy penetration.

The illustration shows grinding and sharpening angles for chisels and planes. These angles vary according to the wood. The smaller the angles the better the cutting action, but the cutting edge must have support, especially against hard knots. It is important not to get the tool hot when grinding, and it should not be ground up to the cutting edge, otherwise the temper and cutting edge are affected. Grinding can be done on a grinding head or an emery belt. The method of sharpening a plane-iron is illustrated under the heading PLANES.

In sharpening a saw, the edge should first be straightened, or breasted, with a flat file and the teeth should then be set. This means spreading alternate teeth to opposite sides to give a saw-cut thicker than the blade of the saw for clearance. Setting may be done by means of a saw-set, by hammer and punch, or by hammer and set. If the setting is not uniform on each side, the saw will run, that is, it will not saw in a straight line.

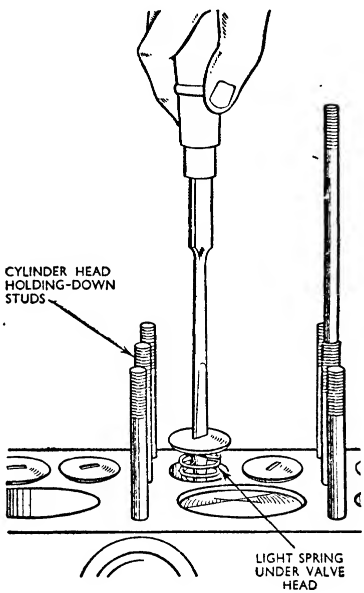
The sharpening of machine saws is done mechanically.

GRINDING HEAD. A localized term for an abrasive wheel used mainly for tool cutting. The tool is held on a rest against the wheel as shown in the illustration until the metal has been reduced to the correct angle.



For grinding the appropriate angle on a cutting tool, a mechanical device similar to the above is employed.

GRINDING-IN (Auto. Engineering). The method used to make poppet valves and valve seatings gas-tight. When an internal-combustion engine has been in use for some time, the valves and valve seatings become worn and pitted, thus causing leakage. It is then necessary to restore their surfaces by grinding-in the valves on their seats.



Grinding-in the valves of an internal-combustion engine, using a screwdriver with light spring under valve head.

Take the valve out and apply a carborundum or other abrasive compound to the face of the valve. Then insert the stem of the valve into its guide, preferably with a light spring under the head as shown; most valves are provided with a slot in the head for the insertion of a screwdriver. Grinding-in is carried out by giving the valve a number of quarter turns in each direction. The spring under the valve will lift the latter as pressure is released, and it is desirable to lift

it after every few turns in order to obtain a different disposition of the abrasive.

Grinding-in is completed when a clean, even track can be seen on both valve and seat. All traces of the abrasive must afterwards be removed by washing valves and seats with paraffin. Much time is saved by re-facing the valve on an electric grinder. The seat may require re-facing, depending on its condition. The final grinding of valve to seat may be done by an electric tool, which oscillates the valve.

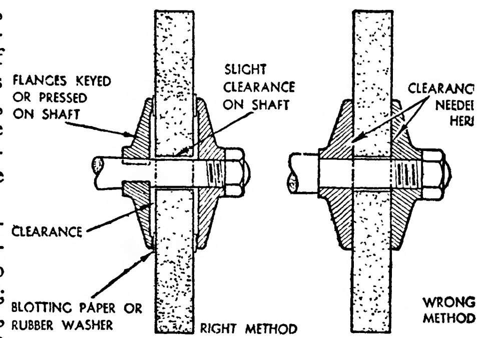
GRINDING MACHINE. A machine originally introduced solely to impart the true shape to steel components warped by the hardening process to which they had been subjected. Even now this remains one of their most important applications, but a long series of developments, both in the design of machines and in the abrasives forming the grinding wheels, has enabled the process to be extended to the surface finishing of components which have not undergone hardening.

In both classes of job, however, the workpiece is generally turned in the lathe to almost the finished diameter; if it has then to be hardened, the subsequent truing which will be needed can be performed only by grinding. Even if the workpiece is not to be hardened, grinding still affords the most satisfactory method in cylindrical work for producing accurate surface finish in a minimum of time.

Cylindrical grinders are used for such items as piston rods, shafts etc.; *internal grinders* for cylinders, bushes, gears etc. and *surface grinders* for imparting a finish to flat surfaces. A small variety, sometimes called *tool-post grinders*, can be attached to the toolpost of a lathe, shaper, or planer, when a small electrically-driven motor provides rotary movement for the grinding wheel, the axis of which is set parallel to the surface to be ground. *Hand-operated portable grinders* are employed when a finish is required on surfaces too difficult for ordinary machines to reach; they are also extensively used in forming the dies required in the sheet metal industry, some being provided with flexible driving shafts, while others are directly driven by small electric motors.

GRINDING WHEELS. Abrasive wheels made of either of two general classes of material: (1) aluminium oxide and (2) silicon carbide. The choice of the material will depend upon what metal is to be ground.

Silicon carbide abrasives (e.g. carborundum) are harder than the aluminium-oxide type and also more brittle. In general the former are found by experience to give better results when grinding materials of low tensile strength; the latter are more suitable for materials of high tensile strength.



Flanges used to clamp grinding wheels should exert pressure only round periphery of flange.

Grinding wheels are made in a great variety of shapes and diameters. Very thin wheels are used for grinding reamers or for cutting-off bar stock to length. Some wheels are dished, e.g. those for grinding milling cutters. Others are of specially small diameter for internal grinding. Grinding wheels, unless very small or exceptionally large, are bushed with lead or Babbitt metal, the bush being absolutely concentric with the wheel. The bush

thus forms the actual bearing to be mounted on the spindle, on which there should be a free fit, but with the play reduced to a minimum.

The flanges used in clamping the wheel should be recessed as shown in the left-hand drawing of the illustration so that they exert their pressure only around the outer periphery. This prevents the wheel from cracking. To make the clamping pressure more even, a washer of rubber or blotting paper is inserted between flange and wheel. The peripheral speeds of grinding wheels vary from 5,000 to 7,000 ft. per min.; in general the harder wheels are allowed to run faster than soft ones.

GROUND COAT. A foundation coat of paint whose characteristics are governed by the treatment which is to follow. If the finish applied is to dry with a dull surface, the ground must be closely related in colour and tone, must dry with a glossy finish and be applied not longer than the day before.

For gloss paints, varnishes and enamels which dry with a bright surface, and as a ground for graining and marbling, the ground must dry firm and hard with but little gloss; if several days elapse between its application and subsequent treatment it must be cut down with a damp, abrasive paper and sponged off with clean water.

In the case of motor-coach and car bodies and small factory-produced articles, the foundation coat has special inherent qualities which promote adherence when it is applied directly to the prepared iron base and fused. It is actually the first coat of enamel applied, but is invariably called by enamellers not the "first" but the "ground" coat.

GROUNDS. Wood battens of varying widths used as bases or fixings for items of joinery, such as door frames, architraves around window openings, skirtings, dado panels, chair and picture rails.

Grounds are frequently used as screeds (q.v.) to assist the process of plastering, and to ensure that the plastering material is applied to the

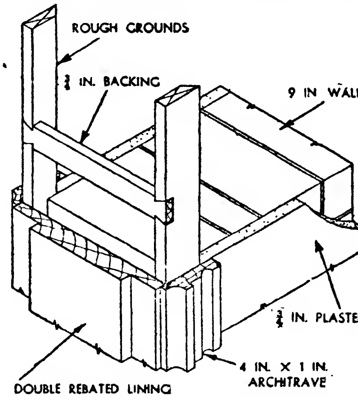


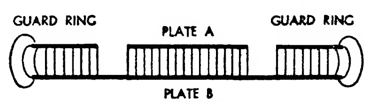
Diagram showing use of grounds as a means of fixing double rebated lining.

required thickness, so that the finished plaster face is true and plumb.

GROUND WAVE. A radio wave which reaches a receiver directly from the transmitter, as distinct from one that is reflected from the ionosphere. See RADIO-WAVE PROPAGATION.

GUARD PLATE, see MACHINE GUARD.

GUARD RING. An electrical device used for eliminating fringing of an electric field. The diagram shows the



Fringing takes place between the edge of plate B and the guard ring, where it does not matter, whereas the field between plates A and B is uniform.

use of a guard ring in a simple condenser consisting of two circular plates marked A and B. See FRINGING.

GUARD WIRE. An earthed wire, situated between an overhead electric line and earth or other lines, forming part of an arrangement for catching and/or earthing the live wire in the event of its breakage.

The term is also used to denote a wire arranged to side-track current leaking over the surface of a dielectric and to divert it from an instrument

which measures current through the dielectric. See DIELECTRIC.

GUDGEON PIN. The hardened-steel pin which secures the piston of an internal-combustion engine to the small end of the connecting rod and allows the latter to swing freely in relation to the piston; also sometimes called the piston pin. The gudgeon pin may be held securely to the connecting rod or in the piston. It is said to be "fully floating" when it is free to move in both components and is prevented from excessive endwise movement by circlips (q.v.).

GUILLOTINE. A mechanical device used to trim or cut sheets of material such as paper or metal. In metallurgy the term is used to denote a shearing machine used for reducing sheet metal to size. Designs range from simple "crocodile jaw" types, as used in rolling mills to shear packs as rolled, to designs capable of really accurate work.

A primary requirement in all accurate guillotine work is that the sheet should be as flat as possible; although it is possible to adhere fairly closely to a scribed line with simple shears even on a buckled sheet, the sheet cannot be marked out accurately. A squared sheet will, for example, be out of register if tested by turning over after shearing. A more serious difficulty is that bad buckling makes accurate adherence to a marked line impossible. Modern guillotines therefore incorporate a hold-down device which comes into operation before the blades descend. Given flat material and accurate marking, such machines can work to close tolerance with high output-rate. Guillotines are also used in papermaking and bookbinding.

GULLEY TRAP. A trap fitted at the point of connexion of the waste pipe with the underground drain. Three kinds of gulley trap are shown in the illustration. They are no-inlet, back-inlet and side-inlet types, and it will be noted that the point of discharge of the waste pipe is above the water seal (q.v.).

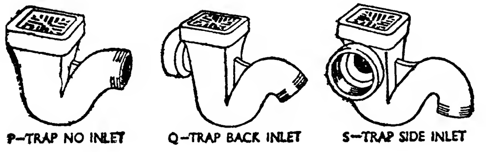
GUM. The coagulation of sap upon the surface of growing timber to close a wound; characterized by being soluble in water. Gums are used as a fixative for paper and pencil drawings; also in the preparation of water-soluble varnishes. They are named after the country of their origin and also the plant from which they are derived. For instance, Gum Arabic (q.v.) and Gum Acacia for the same article. See RESINS.

GUM ARABIC. A water-soluble colloidal exudation from the acacia tree, used in the printing and bookbinding trades. In the former it is used in solution to induce a hydrophilic film on the non-image sections of a lithographic surface; and sometimes in lithographic etches to serve as a combination gum-etch. The viscosity of the etch is thus increased and local control is easier; also the action of the etch is retarded.

Gum solution keeps for some days if cool but it readily putrefies and is useless when sour; it should be made freshly in preference to adding preservatives. Certain inorganic substitutes for gum have been produced, e.g., cellophas W.F.Z. in Great Britain, Kemigum in U.S.A. and Glutofix in Germany.

Gum arabic has many uses in the stationery trades, e.g. gumming of envelopes, local or complete application to labels, stamps, receipt forms and the like. It must not be used in a sour condition or the deposit will remain sticky. It is sometimes used in conjunction with glycerine or a substitute to obtain a flexible film.

GUNMETAL. One of the oldest known alloys, and one that is still in great demand owing to its excellent foundry and mechanical properties



Three types of stoneware gulley trap with discharge point above water seal.

and good resistance to corrosion, especially against sea water.

Admiralty quality gunmetal formerly contained 88 per cent copper, 10 per cent tin and 2 per cent zinc, and the mechanical properties required were 16 tons per sq. in. tensile strength with 8 per cent elongation. To permit the use of scrap metals and to conserve tin the composition has been modified to 86 per cent copper, 6 to 8 per cent tin, 4 to 6 per cent zinc, and 1 to 3 per cent lead, accompanied by a lowering of the mechanical properties to 14 tons per sq. in. tensile strength and 8 per cent elongation.

The alloy is much used for such duties as pump impellers, and casings, and many other applications where good resistance to corrosion is essential. Unless melted under proper conditions, it is subject to the defect known as incipient shrinkage (q.v.). For hydraulic work, the addition of several per cent of lead is beneficial. Lead is insoluble in bronze in the solid state, and, owing to its low melting point, remains liquid long after the rest of the alloy is solid, and so tends to fill any cavities formed.

GUNSTOCK DOORS, see Doors.

GUNSTOCK JOINT, see Joints.

GYPSUM, see Plaster of Paris.

GYROPLANE. An aircraft which obtains its lift from a rotor which is rotated by the air forces acting on it; such machines have no fixed wing surface. The gyroplane differs from the helicopter in that the rotor of the gyroplane is not continually driven by the engine, whereas that of the helicopter is. In the gyroplane the engine is, however, as a rule used to start-up the rotor from rest while on the ground; before take-off a clutch in the drive is disengaged, and the engine thereafter drives only a normal aircraft propeller unit. See Autogiro.

HACKSAW MACHINE. A machine designed for operating a hacksaw. In the simplest type, a frame similar to a hand-operated saw, though of much heavier construction, is reciprocated by a connecting-rod attached to a driving disk or crank, the stroke of the saw being adjusted by varying the eccentricity of the crankpin. Sliding weights are often used, in addition to the heavy frame, to give various pressures on the blade. In some types a ratchet feed is used. Power is applied to the ratchet fingers by a spring under compressive stress, the amount of compression also governing the pressure on the blade to suit the work.

Another form of power hacksaw has a cylinder filled with oil under pressure from a pump, the pressure being transmitted in turn to the blade. The blades usually have a carbon content of about 1 per cent, with from ½ to 2 per cent tungsten and small, but vital, proportions of manganese, chromium and vanadium. The two common pitches for the teeth are 10 and 14 per in. In allowing for the cutting speed of the blades, it must be realized that the actual speed is constantly varying, being zero at each end of the stroke and attaining a maximum in the middle. In all estimations of blade speed, the rate of movement at the middle of the stroke (i.e. the maximum) is the speed actually considered.

HAFNIUM (Hf). Atomic no. 72; atomic wt. 178·6; a metal usually found associated with zirconium; density 12·5. It is tetravalent, forming hafnium oxide, HfO_2, and hafnium chloride, $HfCl_4$.

HALF-SHAFT, see Axle.

HALF-SPEED SHAFT. The shaft of an internal-combustion engine which is geared to rotate once to every two revolutions of the crankshaft. The term usually refers to the camshaft.

HALF-TIMBER CONSTRUCTION. A style of constructing timber buildings, current during the Gothic period of architecture, in which the timber framing was exposed upon

the exterior walls of the buildings. The spaces between the framing members were filled with brickwork or rubble and covered with lime stucco or pargetting.

During recent years, an attempt has been made to reproduce the same effect by applying a system of timber framing to external brick walls, and covering the brickwork surface between the timber members with cement stucco. The timber framing, when used in this manner, fulfils no functional purpose, and is purely decorative. In work of this character, the timber members should be rebated along their back edges so as to form a key for the stucco, and to prevent the appearance of unsightly joints, which are likely to occur by the contraction of the materials.

HALF-TONE INK. Ink used for printing on hard, smooth-surfaced papers which allow little or no penetration. Fine pigments in high concentration are combined with oils of good drying qualities.

HALF-WAVE AERIAL. A dipole, or Hertz aerial. An aerial with an overall length equal approximately to half a wavelength. See AERIAL.

HALOGENS. A name for the elements fluorine, chlorine, bromine and iodine, all of which can be obtained from sea water. The above four elements are closely related in their chemical properties.

HALVING JOINT, see JOINTS.

HAMMER (Eng.). A tool, generally of hardened and tempered steel, most commonly used by fitters and machinists. Hammers range from 6 oz. to 2½ lb. in weight; those weighing about 1 lb. are by far the most common. One end of the hammer-head is ground to a cylindrical shape with a flat surface known as the face; the other end, called the peen, may be either rounded (ball peen) or wedge-shaped, the latter being used chiefly for swaging or riveting.

The hole, or eye, through the hammer-head, into which the shaft fits, is smaller at the middle than at the ends; to ensure a good fit the shaft is given a cut at the end and fitted so that it fills one end of the eye. A mild-steel wedge is then driven tightly into the cut at the end of the shaft, swelling the wood against the hammer head and making it tight. Some fitters make burrs on these wedges to prevent them from working loose, since a loose hammer-head is most dangerous. Sledge hammers, usually with either 7-lb. or 14-lb. heads, are much used in boiler work and other heavy fitting processes. When used with a set, or chisel, held in a round-wire handle by another operative—e.g. for cutting-off rivet heads or punching out rivets—some means should be used to prevent the severed portions from flying off uncontrollably. A small hand-brush held against the rivet head to be cut will effectively stop its flight.

Hammers with heads made of lead or Babbitt metal are used instead of steel hammers where the latter might injure the work, e.g. for brass or gun-metal fittings which may need some impactive blow when held in a vice, or to drive the workpiece on to a mandrel.

HAMMER-HEAD KEY, see JOINTS.

HANDRAIL BOLT, see BOLT.

HARDNESS. The resistance of a metal to local penetration, or to the removal of portions of it. The influence of hardness in industrial materials is nowhere more important than in the case of steel and its alloys. Steel is hardened by heating in a furnace to the requisite temperature followed by quenching; i.e. plunging it at once into a suitable cooling liquid.

It is essential that the heating should be as uniform as possible, and that the furnace temperature should be the lowest at which the desired hardness could be obtained; moreover, the heat should be rising when the steel is removed. Non-uniform heating produces an irregular grain structure, sets up internal stresses, and can even cause cracks in the surface. If the critical temperature (the correct hardening temperature) is exceeded, the grain is coarser and more open;

the strength, though not necessarily the hardness, is reduced. The critical temperatures at which structural changes occur vary with the carbon content, and are generally lower for a high-carbon than for a low-carbon steel.

Of these critical temperatures, two have been specially named the *decalescence* and the *recalescence* points. Steel which contains hardening carbon and is above the decalescence point has no magnetic properties, and this has been turned to account in designing apparatus for estimating the correct hardening temperature.

Of the many methods of measuring the hardness of metals, the Brinell and the Rockwell are probably the best-known.

The former method involves the measurement of the spherical indentation produced by a known load applied to a hard steel ball of known diameter. The Brinell hardness number is the ratio of the load on the ball in kilograms, to the surface area of the indentation in square millimetres. The Rockwell test involves the measurement of the depth of penetration of either a $\frac{1}{16}$ in. steel ball or a spherical-conical penetrator. A minor load is first applied and removed, the indentation being measured; then the scale is reset and a major load is applied. An initial load of 10 kg. followed by a final (major) load of 100 kg. (with the steel ball) or 150 kg. (with the cone) is applied. The Vickers Diamond Pyramid Test employs a square diamond pyramid.

Mohs' scale of hardness, in which natural materials were graded in the order in which each would scratch the next lower in the scale, was probably the first method devised for measuring hardness. This method is, however, impracticable in testing metals. Instead, indentation methods, in which a hardened-steel or diamond penetrator is forced into the specimen under a standard load, are now almost universally employed. The measure of hardness, or hardness number, is expressed either as the ratio of the applied load to the surface area of the indentation made (Brinell principle), or determined on an arbitrary scale, by the depth of the impression made (Rockwell principle). See BRINELL HARDNESS TEST.

HARD VALVE. A radio valve possessing a high degree of vacuum.

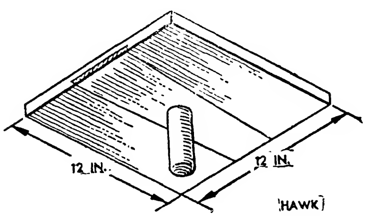
HARD WALL PLASTERS. Prepared calcium-sulphate powders, used in combination with water as the final film upon plastered surfaces. Their chief advantage is that they may be painted with oil paint as soon as the surface will stand the passage of the paint brush. They must not be used in admixture with lime putty, but, used with an equal quantity of whiting and made into a stiff paste with water, they form a good stopping for cracks in old plaster. See KEENE'S CEMENT.

HARMONIC. A frequency which is a direct multiple of a fundamental frequency (see FUNDAMENTAL). In radio circuits, harmonics are produced accidentally or by design, by systems which are non-linear in response. If accidentally generated they create distortion, but they are sometimes intentionally introduced for purposes of frequency multiplication. Harmonics always bear the above relation to fundamental frequencies. Indeed, the fundamental is often termed the first harmonic. Each harmonic of a fundamental frequency is an integral multiple of the fundamental. Thus, in the case of middle C on the piano (it has a frequency of 256 cycles per second), the second harmonic is the C an octave higher, 512 cycles per second; the third has a frequency of 768 cycles per second, and so on. There are, however, the overtones accompanying a note on a musical instrument which do not bear this exact relationship with the fundamentals. Incidentally, it is the number and relative strength of all these overtones including the harmonics which enable a listener to distinguish between two different musical instruments, e.g. a saxophone and a trumpet, playing the same fundamental note.

HARMONIC ANALYSIS. The mathematical breaking-down of a

complex electrical, or other, waveform into its sine-wave components and its constant component, if any. Any waveform, no matter how irregular, will be found to consist of a number of sine waves having different frequencies, together with a constant term, which may be zero, provided that the original waveform repeats itself in a regular manner. The analysis may also be carried out geometrically or electrically. See HARMONIC.

HAWK. A tool used by builders for holding a small quantity of plastering material ready for application to the



Usual dimensions and general constructional features of a builder's hawk.

wall or ceiling surface, or for holding mortar in pointing brickwork. It consists of a flat piece of yellow pine, about 12 in. square, to the underside of which is attached a small handle. To prevent warping, however, the board is usually made up of wedge-shaped pieces, as shown in the accompanying illustration.

HEAD, see CASED WINDOW-FRAMES.

HEADER TANK. A tank or vessel in which is stored a reserve of fluid for systems in which there is likely to be a loss during operation, or where it is necessary to allow for varying amounts of fluid in circulation, due to variations of temperature, such as internal-combustion engine cooling systems, or hydraulic systems in aircraft for operating retractable undercarriages, flaps etc.

HEADPHONES, see TELEPHONE RECEIVERS.

HEADSTOCK. The part of a lathe which carries the spindle, with either a revolving faceplate or chuck, according to the type of work to be done. On a lathe it is distinguished from the tailstock (q.v.) which does not rotate, but can be moved nearer to or farther from the headstock, thus providing a movable centre whose position can be adjusted to suit the length of the workpiece.

In a planing machine, the headstock is the part supporting the cutting tool. Also in some measuring machines the movable head is termed the headstock, whilst in textile machinery it denotes the part containing the main gearing and drive for a beam.

HEATER. In a certain type of radio valve, a filament which heats the cathode but does not itself emit. In such a valve, which is said to be indirectly heated, the cathode is generally cylindrical in form and encloses the heater, which is electrically insulated from it. See INDIRECTLY HEATED VALVE.

HEAT OF COMBUSTION. A figure denoting the amount of heat evolved when 1 gram-molecule of the substance burns in oxygen at a constant volume. Thus methane, CH_4, has a molecular weight of 16, and 16 grams of methane when burning in a constant volume of oxygen evolve 210,000 calories.

HEAT OF FORMATION. The heat evolved when 1 gram-molecule of a compound is formed from its elements at constant volume.

HEAT OF REACTION. The amount of heat evolved in a reaction at constant volume between specified amounts of the substances concerned. Thus, the equation $H + Cl = HCl +$ 22,030 calories, states that 1 gram of hydrogen combines with 35·4 grams of chlorine to form 36·4 grams of hydrochloric acid with the evolution of 22,030 calories of heat.

HEAT TREATMENT. Any process involving heating and cooling applied to a metal or alloy to modify its properties. Thus heating for the purpose of melting a metal or alloy, or for the purpose of making a forging, is excluded from the meaning of this definition.

The heat treatment of steel can include the several processes of

annealing; the case-hardening of low-carbon steels; the hardening and tempering of high-carbon steels. For plain carbon tool steel the heat treatment consists of heating-up to 1380 to 1550 deg. F. (according to carbon content); quenching in water at 70 deg. F., during which process the steel itself should not fall below 212 deg. F.; tempering by reheating at once in oil, in a furnace, or in a salt bath, to a temperature of 350 to 375 deg. F. for relieving strains, or 400 to 500 deg. F. for relieving strains and reducing brittleness, or 500 to 600 deg. F. for relieving strains and toughening.

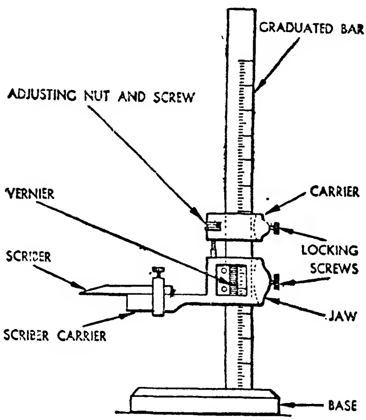
For high-speed steel the treatment will vary greatly with the composition; but for 18 per cent tungsten steel the operations are: (1) annealing by heating to 1600 deg. F. and allowing to cool slowly in a furnace (*not* in air); (2) preheating to 1600 to 1700 deg. F. in a furnace before hardening; (3) heating for quenching by transferring the preheated steel to a furnace in which a temperature of 2250 to 2400 deg. F. is maintained; (4) quenching in oil (kept cool in a water-jacketed vessel) sufficiently to allow the temperature to drop 200 to 300 deg. F. and (5) tempering in a bath or furnace kept at a steady temperature—which may be initially 300 to 400 deg. F., increasing up to the tempering temperature of, say, 1150 deg. F. for high-speed steel or 1200 to 1300 deg. F. for steels which contain cobalt.

It is very important to ensure even penetration of the heat throughout the steel. For tool steels, tempering below 850 deg. F. is seldom practicable, since the resulting tool will be too brittle. See AGEING, AGE-HARDENING, ANNEALING, BOX ANNEALING, CLOSE ANNEALING, LEAD BATH, NORMALIZING, PROCESS ANNEALING, QUENCHING, SALT BATH, STRESS RELIEVING and TEMPERING.

HEAVISIDE LAYER. See IONOSPHERE and RADIO-WAVE PROPAGATION.

HEIGHT GAUGE. An instrument, shown in the illustration, used on marking-off tables, and by toolmakers and machine operators to gauge the height of a surface or line on a workpiece to be machined above a given plane or datum level. As will be seen, it consists of a comparatively massive base, the underside of which is machined perfectly flat; the base supports a single vertical, graduated steel strip or bar of light, rectangular section, up and down which a scriber carrier is free to slide.

This carrier, which has a milled screw to clamp the actual scriber in position, is made integral with a sliding "jaw", having a vernier scale, which is free to move up and down



Gauges of the type shown here are used by machinists and toolmakers.

the bar; it is set roughly to the desired height, the final setting being effected by the use of another carrier attached to the jaw by an adjusting screw. When the correct adjustment has been carried out, a locking screw clamps the whole sliding assembly in position; the reading can then be taken from the vernier scale.

Similar instruments called *depth* gauges are used for measuring the depth of "blind" holes which cannot be conveniently estimated by other means. In depth gauges the sliding assembly carries a thin strip which is inserted in the hole, and the fixed jaw (the equivalent of the base in the height gauge) is then set to the

surface in which the hole is drilled. The vernier scales are used in exactly the same way.

HELICAL GEARS. Gears in which the pitch-surface is a cylinder, itself carrying the helical curves with which the teeth engage.

Helical gearing (Fig. 1) has acquired a greatly increased range of applications in recent years. It can be used

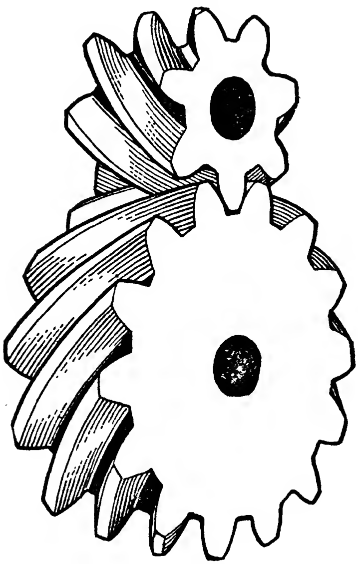


Fig. 1. Helical gears are used when very smooth operation is required.

instead of spur gearing to gear together two parallel shafts, where it gives a smoother action than spur gearing of the conventional type. It is also widely used to connect, as shown in Fig. 2, non-parallel shafts, which need not necessarily lie in the same plane, and has given good results with low powers. To prevent end thrust, double rows of helical teeth (both right-hand and left-hand) are cut on the wheels; such double-helical gears are often called, from their appearance, "herring-bone" gears.

The cutting of the teeth of helical gears is a highly developed art, and, though it can be performed on milling machines, is usually done on gear-hobbing machines. The angle for the helices of gears driving parallel shafts will be governed to some degree by

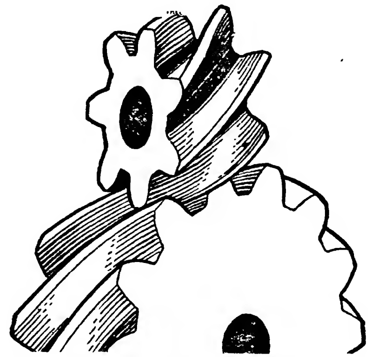


Fig. 2. When two non-parallel shafts are to be driven, spiral gears are used.

the permissible end thrust; a larger angle gives smoother action, but increases the thrust, and therefore a compromise has usually to be sought.

If herring-bone gears (see Fig. 3) are adopted, larger angles can be used. In motor vehicles, angles up to 45 deg. are employed, the object being to

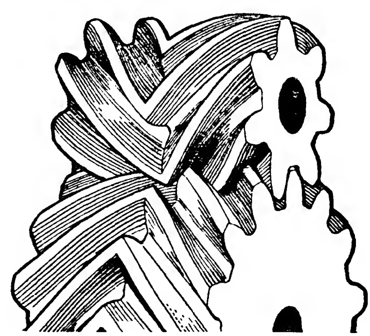


Fig. 3. With herring-bone gears, difficulties of end-thrust are overcome.

secure reduction of noise by smoother action in the gears. Experiments have shown, however, that above an angle of 20 deg. little reduction in noise is obtainable by increasing the helix angle.

HELICOPTER. A flying machine that can ascend and descend vertically,

by means of airscrews revolving in a horizontal plane. To be of any practical value, it must also be able to move forward under its own power.

HELIUM (He). Atomic no. 2; atomic wt., 4·003; a gas present in the atmosphere to the extent of 0·0005 per cent by volume, and in some natural gas in the United States, in which it is present to about 1 per cent; b.p. −268·8 deg. C. It is chemically inert, and forms no compounds. As it is very light and is incombustible, it has been used extensively for filling balloons and airships.

HENRY. Symbol, H. The practical unit of inductance (q.v.). A circuit has an inductance of one henry if an e.m.f. of one volt is produced when the current changes at the rate of one ampere per second. An inductance of one henry has a reactance of 314 ohms at 50 cycles per sec. See ELECTRICAL UNITS and REACTANCE.

HEPTODE. A radio valve having seven electrodes, that is, five grids in addition to the cathode and anode.

HERRING-BONE STRUTTING. A system of short diagonal struts crossing each other in pairs, and fixed between timber joists to assist in stiffening a timber-joist floor.

The strutting should form an unbroken chain across the floor, and is intended to prevent side-buckling of the joists. Its effectiveness will depend largely upon the wedges, or packing, between the end joists and the compassing walls of the building.

HETERODYNE ACTION, see FREQUENCY CHANGER.

HETERODYNE PRINCIPLE (Radio). The production of beats which have a frequency equal to the difference between two higher frequencies. See BEAT FREQUENCY, FREQUENCY CHANGER and SUPERHETERODYNE RECEIVER.

HEXODE. A radio valve with six electrodes, that is, four grids as well as the anode and the cathode.

HIGH-DUTY CAST-IRONS. A term used in metallurgy to denote high-strength irons; special-purpose

CAST-IRONS—TRANSVERSE TEST REQUIREMENTS

DIA. OF TEST BAR in.	DISTANCE BETWEEN SUPPORTS in.	SECTION OF CASTING in.	MINIMUM BREAKING LOAD lb.			
			GRADE 1	GRADE 2	GRADE 3	GRADE 4
0·6	9	Less than $\frac{3}{8}$	570	635	715	865
0·875	12	$\frac{3}{8}$ to $\frac{3}{4}$	1270	1420	1620	1910
1·2	18	$\frac{3}{4}$ to $1\frac{1}{8}$	2120	2370	2630	3130
1·6	18	$1\frac{1}{8}$ to $1\frac{5}{8}$	4800	5400	6000	7010
2·1	24	Over $1\frac{5}{8}$	8000	8850	9850	11200

TENSILE REQUIREMENTS

DIAM OF TEST BAR in.	AREA sq. in.	ULTIMATE STRESS TONS PER SQ. IN.			
		GRADE 1	GRADE 2	GRADE 3	GRADE 4
0·399	—	16	19	23	26
0·564	0·25	15	18	22	25
0·798	0·50	14	17	20	23
1·128	1·00	13	16	19	22
1·596	2·00	12·5	15	18	21

irons, such as those possessing great corrosion resistance, are not included (See AUSTENITIC CAST-IRON).

High strength is obtained by reducing the carbon content to 3.0 per cent or less; by inoculation of the metal in the ladle with silicon-containing compounds such as ferro-silicon or calcium silicide; or by the addition of small proportions of alloying metals including nickel, chromium, copper, molybdenum etc. Whichever method is used, reduction of the carbon content is essential and may suffice in itself.

Reduction of the phosphorus content to below 0·5 per cent is also desirable. The silicon content should be adjusted to give an all-pearlitic structure with a combined carbon figure of approximately 0·9 per cent. The amount of silicon required will depend on the amount of alloys added, nickel and copper, like silicon, tending to promote graphitization, whereas chromium and molybdenum have the opposite effect. To obtain the required low-carbon and phosphorus contents, a good proportion of steel scrap is desirable in the charge, as much as 90 or 100 per cent being sometimes employed. Four grades are specified in British Standards Specification No. B.S. 786, given in the table on the previous page.

High-duty irons are finding increasing application in engineering; for example, grades 3 and 4 in the above specification are frequently employed for crankshafts of internal-combustion engines, for which duty steel forgings were formerly employed.

H.F. (Radio). High Frequency (q.v.).

HIGH FREQUENCY (H.F.). In radio, a term meaning oscillations whose frequency is supersonic, i.e. above audibility. More often spoken of as radio frequency, when in this connexion.

HIGH-PASS FILTER, see FILTER.

HIGH TENSION (H.T.). In radio apparatus, a term applied to the high-voltage system associated with the anode current supply for the valves. The term is purely relative; in battery receivers it is seldom more than 120 volts, while in transmitters, it may be many kilovolts.

HINGE MOMENT. The moment (force acting at a lever arm) which has to be applied to an elevator or flap in order to operate it; that is, to set it over to the required position from neutral. See HINGE-MOMENT COEFFICIENT.

HINGE-MOMENT COEFFICIENT. A non-dimensional coefficient relating the hinge moment (q.v.) of an elevator or flap to its size, the speed at which the aeroplane is flying and the atmospheric density. If we let

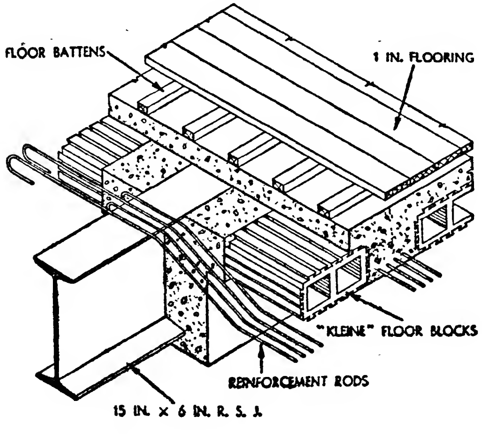
H = hinge moment in lb. ft.;
$\bar{c}$ = mean chord of control or flap in ft.;
S = area of control or flap in sq. ft.;
ρ = the air density in slugs/cu. ft.
v = the speed of the aeroplane in ft./sec.

then:—

$$H = C_H \bar{c} S \tfrac{1}{2} \rho v^2$$

where C_H is the hinge moment coefficient.

HOLLOW-TILE FLOORS. Floors of concrete formed over hollow tiles or burnt-clay blocks. These are used to assist in the spanning of the spaces between the secondary steel joists. To eliminate timber shuttering for the support of the concrete,



Hollow-tile floors are used, in place of concrete, because they are considerably lighter.

the tiles are placed so as to rest upon, or receive support from, the secondary joists, and the concrete floor slab is formed over the top surface of the hollow tiles. Such floors are known as *self-centring floors*.

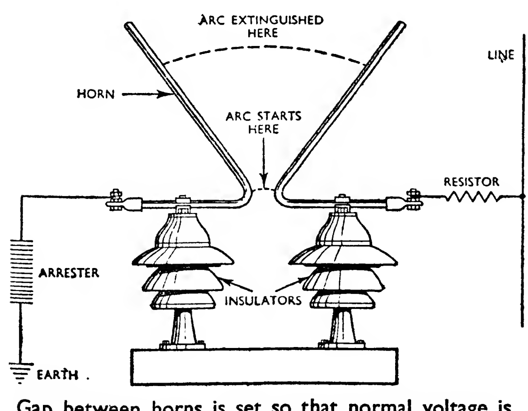
Another type of hollow-tile concrete floor is formed by filling the spaces between the concrete ribs of a ribbed floor with hollow tiles. The inclusion of hollow tiles is intended to produce a level under-surface to the floor slab and so assist in forming a base for the plastered ceiling. Hollow-tile floors have largely replaced solid-concrete floors, because they are lighter in weight.

HOMING DEVICES, see DIRECTION-FINDING.

HOPKINSON TEST. A method of testing two electrical machines such that one drives the other mechanically, while the second supplies electrical power to the first. It is thus necessary to supply only the total losses from an external source.

HOPPER WINDOWS, see WINDOWS.

HORN GAP. A gap in an electrical circuit, of the form illustrated in the diagram. An arc, starting at the narrow part, is driven up the horns by convection and/or electromagnetic action, and is ultimately extinguished. See ARRESTER.



Gap between horns is set so that normal voltage is just unable to cause a spark, whereas a surge makes the gap break down. The energy of the surge is dissipated in the arrester and resistor, while the resistor also serves to limit current if an arc occurs between live horns of adjacent gaps.

HORSE-POWER. The unit for measuring and comparing the working capacity of engines. It was first established by James Watt, who calculated that the work done by the strongest dray horses was the equivalent of 33,000 ft.-lb. per minute. This means that if an object weighing 33,000 lb. is raised through a vertical distance of 1 ft. in 1 minute, 1 horse-power of energy has been expended. The H.P. of an engine is, therefore, the number of ft.-lb. of work the engine can perform per minute divided by 33,000.

Brake horse-power (B.H.P.) is the energy obtainable at the flywheel and, owing to friction and cooling losses in the engine itself, is always less than that produced in the cylinder of a heat engine.

Indicated horse-power (I.H.P.) (q.v.) is the gross H.P. developed in the cylinders by the expansion of the gases (including the power to overcome internal losses). It is obtained from readings of pressures inside the cylinders at various piston positions; the whole of the work being performed inside the cylinder is obtained by calculation.

HOSE CLIP. A circular strip of metal with means for reducing its diameter to allow it to grip the outside of a rubber hose. It is used, for instance, on internal-combustion engine cooling systems to ensure a watertight joint between the hose and the metal tube on cylinder block and radiator over which the hose fits.

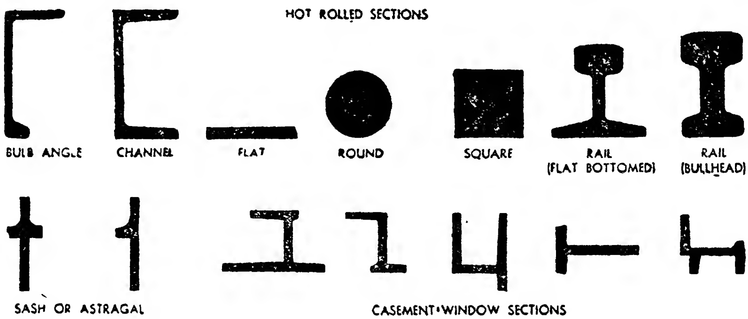
HOSPITAL WINDOWS, see WINDOWS.

HOT-CATHODE VALVE, see GAS-FILLED VALVE.

HOT-DIPPING PROCESSES, see METALLIC COATING.

HOT-ROLLING PRACTICE (Sheet Metal). The two-high mill (q.v.) is the earliest form of rolling process. With few modifications it has consisted, since the first design, of two housings, two rolls, a means of screw-down threaded down through each housing and bearing on the neck of the top roll, and wobblers on the end of each neck of the bottom roll, whereby the mill may be coupled to its neighbours on each side. The usual hot-rolling sequences are as follows, re-heating being accomplished between each stage: 12 B.W.G. or thicker, rolled singly to size; up to 18 or 19 B.W.G. rolled in pairs (see BREAKING DOWN); from 18 to 24 B.W.G., the pairs are doubled to make four sheets; from 24 to 31 B.W.G., the doubles are re-doubled, making eight sheets (in certain cases an extra single sheet may be inserted in the pack before re-doubling to give ten sheets in the finished pack). Owing to the increasing necessity for sheet surfaces free from rolled-in scale, it has become the practice to break-down in water-cooled rolls before transferring operations to the finishing mill.

The foregoing pertains to the hot-rolling of mild-steel sheets, and while the mill design resembles closely the two-high mills now used for stainless steel and aluminium sheets (and for cold-roll finishing of mild steel), the mechanical efficiencies are very different. The main difference between the two designs is in the screwdown mechanism, which in the case of the latter process is designed to give very heavy pressures. See FOUR-HIGH MILL and TWO-HIGH MILL.



HOT-ROLLED SECTIONS

Hot-rolling processes produce a wide variety of sections, each having specific uses.

HOT-WATER SYSTEM. Domestic hot-water systems rely almost entirely for their circulation on convection (see CONVECTION CURRENT) which, stated briefly, means that hot water rises, whereas cold water sinks. In other words, water heated in a boiler rises to the highest level, and it is a simple matter to arrange the piping layout so that constant circulation is ensured, the rate of circulation depending on the difference in temperature of the hot and cold columns.

Two main methods can be employed, the direct and indirect; in the direct method the water for domestic use obtains its heat directly from the fire or heater, whereas in the indirect method water heated by the fire passes through a tube or cylinder in a secondary boiler and gives its heat to the water which will be drawn off at the tap. One advantage of the indirect method is the fact that the same water in the primary boiler is used over and over again, so that after the initial deposit of lime and chalk salts on the inside of the boiler and tubes, no further encrustation occurs.

A simple layout for the *direct* system can be seen in Fig 1. The

essential requirements are boiler, hot-water storage tank, cold-water storage cistern to feed the boiler, vent pipe, flow and return pipes and draw-off pipes and taps. As will be seen, the cold-water feed pipe is attached to the lowest point of the storage tank, while the hot-water, or flow, pipe rises from the top and extends above the highest point of the cold-water cistern, its open end being turned over and downwards. The function of this open vent is to allow the circuit to be filled, and to allow water to be drawn off; it permits air to enter or leave as necessary, so that there is no vacuum or compression. As the vent pipe and the supply pipe form what is virtually a U-tube, and as the water in the vent pipe will be hotter, and therefore lighter, than that in the supply pipe, it follows that the column of water in the vent will stand at a higher level than the water in the cold storage cistern. This is why the vent pipe is carried up above the cistern. The height to which it should be taken depends on the vertical distance from the water level in the cistern to

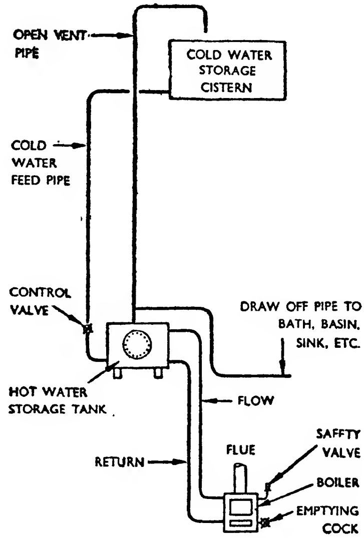


Fig. 1. Layout for the direct system.

the point of entry of the supply pipe in the hot-water storage tank, and a safe rule is to allow one inch of vent above cistern level for every foot of this drop. It is important that the vent should be protected from frost.

The supply and flow pipes should be of a size that will allow the water passing through them to be retained in the boiler just long enough to be properly heated; pipes too small in diameter will cause the water to

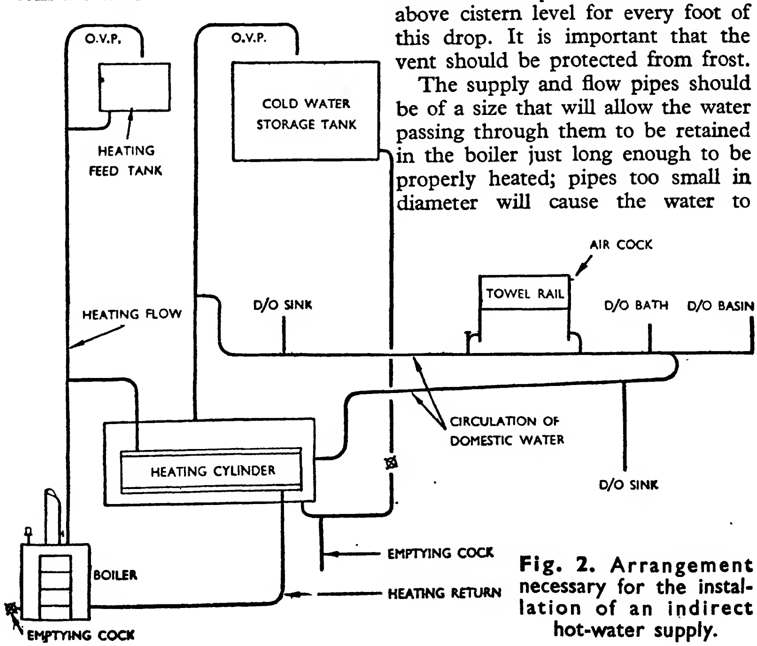


Fig. 2. Arrangement necessary for the installation of an indirect hot-water supply.

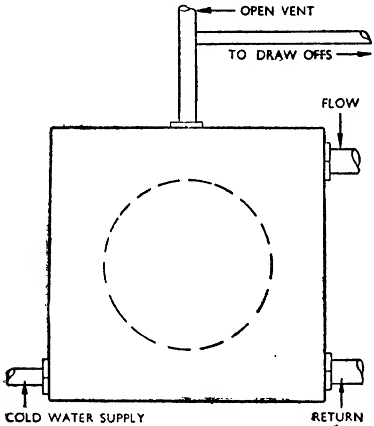


Fig. 3. Connexions to cold-water cistern. Note position of flow pipe.

become overheated, and will soon fur up, while pipes too large, although not rapidly becoming encrusted, will allow too quick a circulation, and consequently re-circulation and waste of fuel. The supply pipe in a hot-water system should supply that system alone and no other, and a control valve should be provided on it in a position near the hot-water storage tank; this is the only valve that is fitted to a domestic hot-water system.

The *indirect* system is shown in Fig. 2. In this there is, as already described, a heating cylinder as well as a boiler with two vent pipes and a separate cold-water feed tank. Water heated by the boiler flows through a cylinder in the heating tank and heats the water used domestically. Also shown in this diagram is a secondary circulation so that a towel rail can be fitted. A secondary circulation is necessary where a towel rail is to be fitted, one pipe being in itself too small to allow of flow and return. Where a tap is to be served some distance away from the hot storage tank, if the pipe is exceptionally long, there should still be a return pipe to allow for circulation, as otherwise the water in the pipe will be cold and will have to be drawn off every time the tap is turned on. The Metropolitan Water Board prohibit a waste of water in this fashion by specifying that a draw-off pipe shall not be more than a certain length excepting where a secondary circulation is installed.

The secondary flow should be taken from the vent pipe at a higher level than is necessary with a straight draw-off, to ensure proper circulation, while the secondary return pipe should be connected to the storage tank at a slightly lower level than the primary flow pipe. Where it is impracticable to connect the secondary return to the storage tank, it may be connected to the primary return pipe, but in this case a non-return should be fitted to prevent cold water being drawn back into the secondary return.

The storage tank may be rectangular or cylindrical. Small rectangular tanks are often fitted in airing cupboards, where they act as a source of heat for drying purposes, but where high pressures are involved the tank should always be cylindrical. A coil of pipe in the airing cupboard is more economical than a tank.

Figs. 3 and 4 show alternative connexions to a hot-water storage

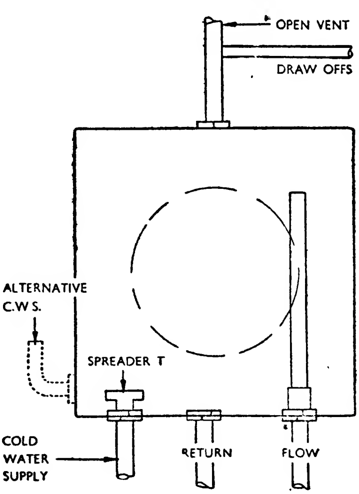
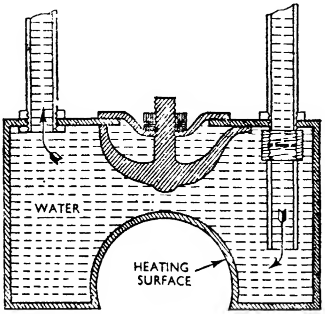
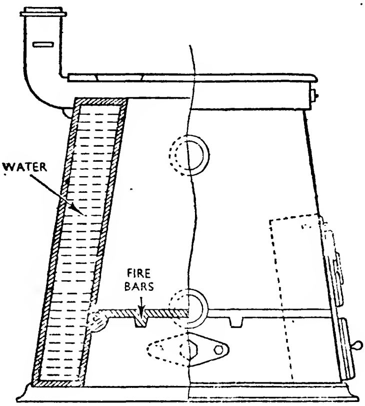


Fig. 4. To ensure that cold water is spread over the bottom of the tank, a T-shaped pipe is fitted as shown.

Fig. 5. Two types of boiler suitable for domestic hot-water systems: (a) for kitchen range, (b) separate boiler.



(a)



(b)

vessel. Comparison will make it clear that although in one case the flow pipe from the boiler enters the storage tank at the bottom, this pipe is actually continued up inside the tank so that the effect is the same as if it were connected at the top. Note also the spreader T; this is important to ensure that cold water is spread over the bottom of the tank instead of being forced up to the top.

The size of the hot-water tank should be such as will provide ample hot water at peak periods. For small dwelling houses calculations should be made on a basis of 15 gallons for a bath, 5 gallons for a sink, and 3 gallons for a lavatory wash basin, with an allowance for extra use above normal.

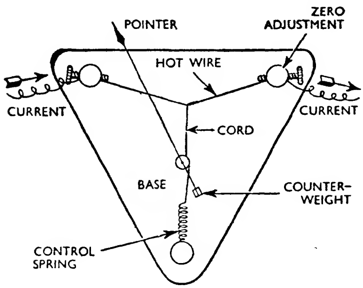
A draw-off cock for emptying the system for cleaning or repairs should be fitted to the lowest part of the system and preferably to the boiler. The use of a gas plug for this purpose is to be condemned, as it causes flooding and splashing. An emptying cock with proper hose union should be employed; the cock should receive periodical attention, and should never be tightened unduly with a spanner or hammer.

Boilers suitable for domestic hot-water systems are shown in Fig. 5, where (a) shows, in section, a simple boiler that can be placed at the back of an open fire or kitchen range, and (b) is the side elevation of the type of boiler usually employed independently, for heating water alone. Boilers can be made of cast-iron, wrought-iron, steel or copper, and vary from the small fireback type, with a heating capacity of 8000 B.Th.U., to large sectional boilers with an output rating of 1,000,000 B.Th.U. The fuels used range from coke, coal and anthracite to oil or gas.

Auxiliary boilers can be fitted for summer-time use in combined heating and hot-water systems, or as "boost" boilers during peak periods of supply. Connexions from auxiliary boilers should be made direct to the hot-water storage vessel, and not to the flow and return pipes of the main boiler; otherwise there will be inter-circulation between the boilers. No valves should be used.

HOT-WIRE INSTRUMENT. An electrical measuring instrument which depends on the elongation of a heated wire, or strip of metal. A simple form of hot-wire instrument is shown in the illustration on the next page.

When the wire is heated by the passage of a current, it expands and the sag increases. The spring-loaded cord, which takes up the sag, drives the pointer of the instrument. As the heating depends on the square of the current, the scale is not uniform. The disadvantages usually associated with these instruments are sluggish oper-



As the sag of the heated wire increases, the pointer is pulled to the right by the control spring. The base should expand at the same rate as the wire, or else changes of air temperature will alter the pointer's position. Special forms of this instrument are used for high-frequency work, when others would be useless.

ation, small overload capacity, and a wandering zero.

For use as an ammeter, the instrument may be shunted, while to use it as a voltmeter, a series resistance is required. Hot-wire voltmeters are little used at power frequencies, because they take relatively large currents.

HOUSING JOINT, see JOINTS.

H.T. (Radio). High tension (q.v.).

HUB. The central part of a wheel, from which the spokes radiate.

HUM. A term applied to alternating voltages or currents appearing in the output of an amplifier, owing to the effect that mains power currents, voltages or fields have on the circuit. In practice, it is not possible completely to eliminate it in mains-operated apparatus, but it can generally be reduced to negligible proportions by careful attention to screening, filtering, wiring, lay-out, choice of components and general circuit design.

HUMP SPEED. The speed at which maximum drag occurs when a stepped hull or float of an aircraft begins to plane. It is found from tank tests on models that the water-drag increases fairly rapidly as the hull moves forward from rest. This increase continues until a speed is reached at which the hull or float rises on its step and begins to plane; that is, when the force supporting it changes from displacement to dynamic reaction; the drag then begins to decrease.

HUNTING. A rhythmic variation in the speed of a governed engine or electrical machine above and below its average speed. See DAMPING WINDING.

HYDRATED LIME (Building). Lime slaked and ground to a fine powder. Hydrated lime is suitable for any purpose in building for which lump lime has been used, but has the advantage of being more compact in form, and free from unslaked particles. It can be mixed as required, and if a hard set is desired a proportion of Portland cement may be added to the lime during the process of mixing the mortar.

HYDRAULIC JACK, see JACK.

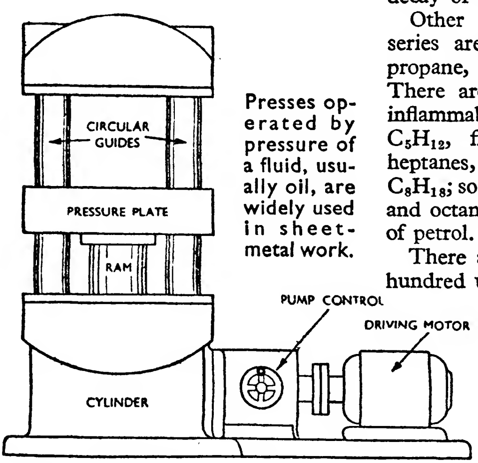
HYDRAULIC PRESS. A press operated by fluid pressure. This method is being increasingly used in sheet-metal work for presses, oil replacing water as the pressure-medium for extrusion or baling operations. The central pumping station, accumulators and long pipe-lines are being superseded by small self-contained high-pressure pump units to each press, a feature which has enabled them to enter the drawing, stamping and plastics industries with great success. Small pump units operate up to 5,000 lb. per sq. in. and give a highly variable and reversible delivery by regulating the throw of the eccentrics actuating the pistons or vanes.

The advantage of oil over mechanical operation is that the length of the stroke and the speed are flexible, with the end-pressure definite and determinable by a pressure gauge. Also, the press may operate at a constant or variable speed over any part of the stroke, whereas the draw stroke of a crank press is made at a diminishing speed with a fixed stroke. This necessitates careful setting of the stroke, for overruns may cause a breakdown.

With hydraulic operation, however,

the minimum pressure for the work in hand may be used, with extended life of the dies; moreover, the machine is safeguarded by a relief valve. For plastic moulding, the ram can be made to stall at any pre-determined pressure, to dwell for a period and then return rapidly, features unattainable with a mechanical press.

Hydraulic presses are available from the smallest sizes for shaft straightening or light assembling, to massive machines used in the aircraft industry. One such machine, of 5,000 tons capacity, weighs 400 tons. The platen is 15 ft. × 6 ft. with an opening of 45in. Four pumps driven by two electric motors of 150 h.p. each supply oil from a tank containing 12,000 gals. to a 6ft. diameter ram. The closing and return speed of the ram is 250 in. per min., and pressing at 13 in. All speed variation and reversal are by pump control, no valve control being included. Triple action can be fitted, using pressure oil for the blankholder, the inner slide and the die cushion equipment. A typical hydraulic press is shown in the illustration.



Presses operated by pressure of a fluid, usually oil, are widely used in sheet-metal work.

HYDROCARBONS. Compounds of carbon and hydrogen; some are gases, some liquids and some solids, a tremendous variety of them being known. The reason for this number is the capacity of one carbon atom to combine with another carbon atom; in this way a group such as CH_3 easily replaces one hydrogen atom in a simple carbon compound, making a more complex one.

Thus it follows that, in methane, CH_4, any hydrogen atom, or all the hydrogen atoms, may be replaced by a CH_3 group, to give $CH_3.CH_3$, or $CH_2(CH_3)_2$. These additional hydrogen atoms can themselves be replaced by CH_3 groups almost indefinitely.

The hydrocarbons are divided into many groups, one of which is that of the paraffins; these have the general formula C_nH_{2n+2}, the first member of this group being methane, a colourless, odourless gas that is the chief constituent of the natural gas found in several parts of the world, especially in North America. It occurs in coal mines, where it is known as fire-damp, and is found in marshy places and formed by the decay of vegetable matter.

Other members of the paraffin series are the gases ethane, C_2H_6, propane, C_3H_8, and butane, C_4H_{10}. There are three different pentanes, inflammable liquids with the formula C_5H_{12}, five hexanes, C_6H_{14}, nine heptanes, C_7H_{14}, eighteen octanes, C_8H_{18}; some of the hexanes, heptanes and octanes are valuable constituents of petrol.

There are in existence more than a hundred undecanes with the formula $C_{11}H_{24}$, and many thousands of possible or known higher paraffins. Paraffin wax is a mixture of solid paraffins from $C_{21}H_{44}$ to $C_{30}H_{62}$.

Ethylene, or olefiant gas, C_2H_4, is produced by the "cracking" of mineral oils; from it alcohol, ethylene dichloride, mustard gas and many other compounds are made. It is one of many members of the series C_nH_{2n}. Acetylene, C_2H_2, is an explosive, colourless gas from which alcohol, acetic acid and acetone can be prepared.

In addition to the above hydro-

carbons, in which the carbon atoms form simple or branched chains, there are many hydrocarbons in which the carbon atoms form rings. The most important of these is benzene, C_6H_6, in which the six groups of CH form the corners of a hexagon. Many derivatives of benzene are known, for instance toluene, $C_6H_5.CH_3$, which is benzine in which one hydrogen atom has been replaced by a CH_3 group. There are three xylenes with the formula $C_6H_4(CH_3)_2$. Naphthalene has the formula $C_{10}H_8$; it has a double-ring structure. Many hundreds or thousands or derivatives of benzine, naphthalene and other ringed hydrocarbons are known. They are called aromatic hydrocarbons, because several of the members of these series have a pleasant smell.

HYDRODYNAMICS, see MECHANICS.

HYDRO-ELECTRIC GENERATING STATION, see GENERATING STATION.

HYDROGEN (H). Atomic no. 1; atomic wt. 1·0078; a light, colourless gas than can be liquefied, by cold and pressure, to make a liquid which boils at −252·8 deg. C. It occurs free in certain natural gases, and is a constituent of all animal and vegetable substances. It is the simplest element and the lightest gas. It is sparingly soluble in water.

In small quantities it is easily prepared by the action of dilute sulphuric acid or dilute hydrochloric acid on zinc. On a larger scale it can be made by the electrolysis of water. For industrial purposes it is made by passing steam over spongy iron obtained by the reduction of certain ores of iron.

Hydrogen is also made from water-gas, which is a mixture of hydrogen and carbon monoxide, obtained by passing steam over red-hot coke. The carbon monoxide can be liquified by cooling the gas to a temperature of −191·5 deg. C. For the manufacture of synthetic ammonia, pure hydrogen is made by mixing water-gas with an excess of steam and passing the mixture over a hot catalyst consisting of oxide of iron mixed with oxide of nickel and oxide of chromium. The carbon dioxide, CO_2, is absorbed by water, and any carbon monoxide remaining is absorbed by a solution of ammoniacal cuprous formate. There are many other ways of making hydrogen.

Hydrogen is an active element chemically, and is particularly so at the moment of its production, when it is known as nascent hydrogen. It can be produced not in molecules of hydrogen but in atoms by burning an electric arc in hydrogen. The atomic hydrogen may be passed through a special kind of blowpipe to form an intensely hot flame, caused not by combustion but by the combination of the hydrogen atoms to form hydrogen molecules.

The compounds of hydrogen are innumerable. It combines with oxygen to form water, H_2O, and hydrogen peroxide, H_2O_2, used to some extent in bleaching. It combines with chlorine to form hydrochloric acid, HCl, with nitrogen to form ammonia gas, NH_3, with boron to form boron hydride, BH_3, with sulphur to form sulphuretted hydrogen, H_2S. The compounds with carbon are several thousands in number (see HYDROCARBONS).

HYDROGENATION. The process of adding hydrogen to a substance by the direct use of hydrogen gas. The chemical combination of the gas and the substance takes place with the help of a catalyst at a suitable temperature.

The process is used on a large scale in the manufacture of margarine from various fats and oils and in the manufacture of petrol from coal. In the latter process the catalyst is usually molybdenum sulphide or tungsten sulphide; the process needs a high pressure, about 250 atmospheres, and a temperature of about 450 deg. C.

HYDROGEN COOLING. The circulation of hydrogen in a closed system for cooling electrical machines, notably alternators. The advantages of hydrogen over air, which is norm-

ally used, are that less energy is used in moving it and that it can absorb more heat.

HYDROPHILIC SOLS, see COLLOIDS (Chemistry).

HYDROSTATICS, see MECHANICS.

HYSTERESIS, see DIELECTRIC HYSTERESIS; MAGNETIC HYSTERESIS.

HYSTERESIS LOOP, see MAGNETIC HYSTERESIS.

ICONOSCOPE. An electron tube, due to Zworykin, and similar to a cathode-ray tube, used in television for scanning an image.

The optical image of the scene to be televised is focused on to a photo-electric mosaic consisting of a mica plate. This plate carries, on its illuminated side, a mosaic surface composed of a very large number of isolated photosensitive globules insulated from one another. The other side of the plate is backed with a metal coating which is the output electrode. A cathode-ray beam produced by an electron gun similar to that used in ordinary cathode-ray tubes scans the image. The scanning beam, deflected by suitable coils, sweeps the mosaic surface from top to bottom in a series of horizontal lines.

The action of the iconoscope is briefly as follows. Each mosaic globule forms a small condenser with respect to the metal backing of the mica plate. Light, in falling upon a globule, causes electrons to be lost through photo-electric emission, and thus the globule becomes positively charged to an amount depending upon the light intensity. The scanning electron beam, on meeting such a globule, replaces the lost electrons. This replacement of electrons corresponds to an electric current which must flow through the load resistance shown between grid and cathode of the amplifier valve in the diagram.

Thus as the beam sweeps over the whole mosaic surface, there will be a series of current pulses through this resistance proportional to the light intensity on the globules scanned. The corresponding voltages are then amplified and passed to the transmitter. See TELEVISION.

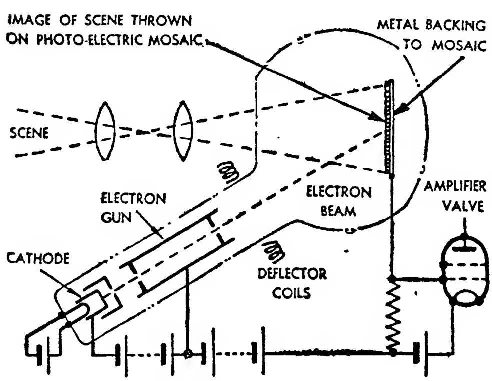


Diagram showing working principle of the iconoscope, which is a development of the cathode-ray tube applied to television transmission.

I.C.W. Interrupted Continuous Wave (q.v.).

IDLER, see IDLE WHEEL.

IDLE WHEEL. A toothed wheel, often referred to as an idler, used in a gear-train in order to obtain the desired spacing of centres, without affecting the ratio of the drive. Sometimes a wheel used as a sprocket to take up the slackness in a chain is called an idler, but this is more correctly known as a jockey or tensioner wheel.

Instances of both usages occur in automobile engineering: of the true idler in the conventional gearbox, where it is used to obtain reverse gear; and as a tensioner in chain-driven timing mechanism to eliminate slackness in the timing chain.

I.F. Intermediate Frequency (q.v.).

IGNITION (Auto. Engineering). The igniting of

the explosive charge within the engine cylinders. In petrol engines, this is accomplished by producing an electric spark inside the cylinder every time the piston has completed its compression stroke. The spark occurs across the points, or electrodes, of a sparking plug screwed into the combustion chamber (see SPARKING PLUG). In order to produce a spark of sufficient intensity, a very high voltage or high tension (H.T.) impulse of between 4000 and 10,000 volts is required. See MAGNETO and BATTERY-AND-COIL IGNITION.

In the compression-ignition, or Diesel engine, however, ignition takes place as a result of injecting atomized liquid fuel into a charge of air heated by compression. See COMPRESSION-IGNITION ENGINE.

ILLUMINATION Symbol: E. The luminous flux falling upon unit area of a surface. It is usually expressed in lumens per square foot. See LUMEN and LUMINOUS FLUX.

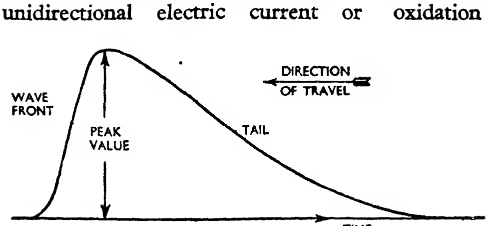
IMPEDANCE. Symbol: Z. The opposition offered by a circuit or part of a circuit to the passage of an alternating electric current. It is measured in ohms and is related to current and voltage by the general form of Ohm's Law, viz.

$$\text{Current (I)} = \frac{\text{Voltage} \quad \text{(V)}}{\text{Impedance (Z)}}$$ so that an alternating e.m.f. of 1 volt produces 1 amp. in an impedance of 1 ohm. Impedance is found as follows:

$$Z = \sqrt{(\text{Resistance})^2 + (\text{Reactance})^2}.$$

See REACTANCE.

IMPULSE (Elec. Engineering). A unidirectional electric current or voltage which lasts for only a short time, possibly only a few millionths of a second. A typical waveform is shown in the diagram.



Typical waveform of an impulse or surge. The steep wavefront denotes a very rapid change of voltage or current which is liable to do considerable damage to electrical apparatus.

INCIPIENT SHRINKAGE. A minor form of shrinkage in metals produced in the same way as ordinary shrinkage, taking the form of fine hair-line cracks, often extending for a considerable distance, round the grain boundaries in certain alloys. Its effects are, therefore, much greater than the actual volume of the shrinkage cavities would suggest. Incipient shrinkage is one of the principal causes of weakness in gunmetal (q.v.), though melting under slightly oxidizing conditions does much to prevent its occurrence.

INCOMPRESSIBLE FLOW. The development of the theory of fluid motion has been assisted by, and based to a large extent on, the concept of a perfect fluid, i.e., a continuous incompressible non-viscous medium. It is upon this concept, together with the assumption that as well as flowing past an aerofoil the air has a tendency to circulate round it, that Joukowski, Prandtl and others built up the theory of lift.

INCONEL. A nickel-chromium-iron alloy containing approximately 86 per cent nickel, 12 per cent chromium, with the balance iron. It combines strength, great toughness and corrosion-resistance with a marked resistance to oxidation contributed by the chromium. It has practically complete resistance to corrosion by food and other dilute organic acids, but most of its uses involve resistance to oxidation rather than corrosion. Parts of furnaces, case-hardening boxes, aeroplane exhaust-manifolds and water heaters are typical uses of inconel.

The resistance of the metal to oxidation is high at temperatures up to 950 deg. C. and it will withstand repeated heating and cooling between room temperature and 950 deg. C. The alloy is

available in most of the usual engineering forms, and, for a material with the strength of 35 tons per sq. in. in the fully annealed condition, it responds well to fabricating operations.

Inconel is easily welded and does not suffer from weld decay, so that no heat-treatment after welding is necessary.

INDENE RESINS, see COUMARONE AND INDENE RESINS.

INDEPENDENT CHUCK, see CHUCK.

INDEXING HEAD, see DIVIDING HEAD.

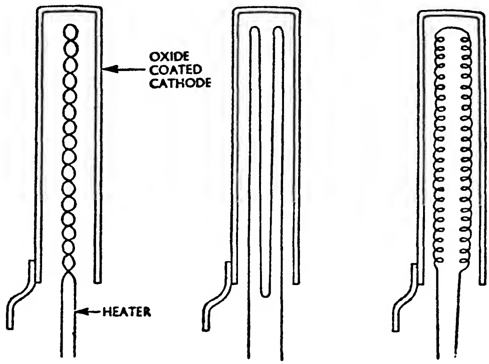
INDIAN STONE, see OILSTONE.

INDICATED HORSE-POWER. The gross power that the engine contracts from the energy liberated by the combustion of the fuel-air mixture in the cylinders. It is proportional to the mean pressure exerted on the head of the piston multiplied by the stroke, and the number of explosions in a given time. The horse-power delivered to the shaft—that which would be measured by a brake connected to the engine—is equal to the indicated horse-power minus the horse-power required to overcome the friction of the engine and that required to drive the supercharger and other accessories.

Indicated horse-power can be measured by an indicator. This instrument, invented by James Watt for use on steam engines, automatically draws a diagram giving the variation of pressure with volume in the cylinder (piston position) during the power cycle. From this diagram the indicated horse-power can be deduced. See HORSE-POWER.

INDICATOR. A substance used to denote the progress or completion of a chemical change. Many indicators are solutions of a dyestuff that changes its colour as the acidity of the solution alters.

INDIRECTLY HEATED VALVE. A radio valve in which the cathode is not heated by the passage of a current through it, as is the case in the directly heated valve (q.v.). An indirectly heated cathode is generally cylindrical, or tubular, in form and is made of nickel or other suitable material and coated with an emitting substance. It is heated by an independent filament, called a *heater* (q.v.), enclosed within it and, usually, insulated from it, as shown in the illustration. Owing to the inherent thermal sluggishness of such an arrangement, indirectly heated valves can be heated directly from A.C. sources without the alternations of the heating current appreciably affecting the anode current.



Typical indirectly heated cathode structures.

INDIUM (In). Atomic no. 49; atomic wt. 114·76; a soft, white metal occasionally obtained in the treatment of zinc residues; m.p. 155 deg. C.; b.p. 900 deg. C. It is sometimes divalent and sometimes trivalent, but its compounds are not of importance industrially.

INDUCED DRAG. The resistance incurred in maintaining an aeroplane in the air, i.e., in producing lift. A simple explanation of the origin of induced drag is as follows: The air flowing past a wing of finite span is deflected downward through an angle ϵ, as shown in the illustration. A part of this deflection is due to the vortices that are shed by the wing tips by the "spilling over" of air from the lower to the upper surface because of the

pressure difference between these surfaces.

However, the lift and drag, which are due to the wing section, or what may be called profile lift (L_P) and profile drag (D_P) act, as indicated, at right-angles and parallel to the mean relative wind direction. The lift and drag (L_A and D_A), as ordinarily used, are measured at right-angles and parallel to the undisturbed direction of the relative wind because they affect the aeroplane as a whole. It will thus be seen that as the profile lift is tilted backwards, a component, or part of it, will thus be acting backwards and retarding the aeroplane. This is known as the induced drag (D_i) so that the total drag (D_A) is made up of the induced drag (D_i) and the profile drag, (D_p).

Note. The difference between the actual profile drag and its component acting parallel to the undisturbed relative wind is small and can be neglected.

The angle through which the air flow is deflected down is called the angle of downwash (q.v.). It will be seen from the illustration that the effect of the downward deflection of the mean relative wind is to decrease the effective angle of attack of the wing; this reduction of incidence is called the induced angle of attack, and for practical purposes may be assumed to be half the angle of downwash, i.e. $\frac{\epsilon}{2}$

The induced drag is directly proportional to the weight of the aeroplane and its span loading (weight divided by the square of the span), and is inversely proportional to the air density and the square of the aeroplane's speed.

INDUCTANCE. Symbol: L. The property of an electrical circuit which causes it to resist changes in the

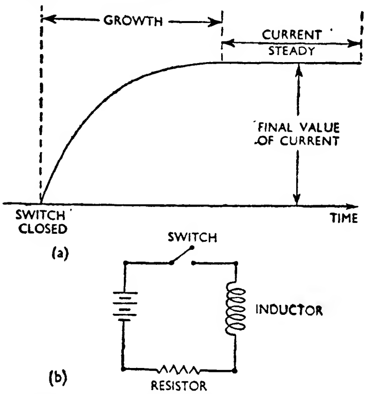
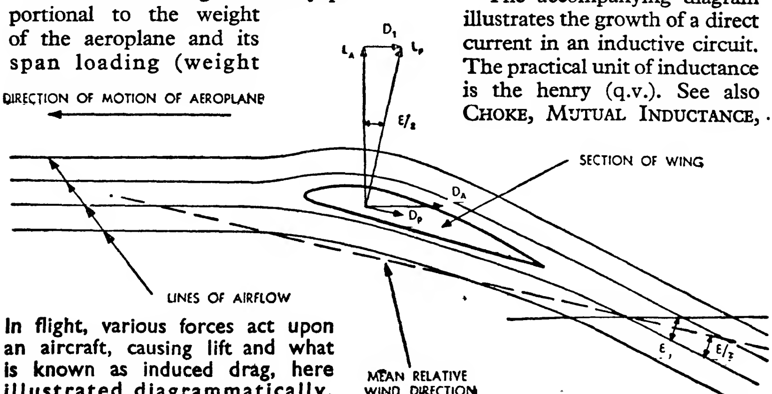


Diagram (a) illustrates what happens when the switch in diagram (b) is closed. What is usually termed the time constant of the circuit is the time taken for the current to reach 62·3 per cent of its final value.

current flowing. This property is similar in effect to mechanical inertia.

When the current increases, a back e.m.f. is set up which delays the increase, whereas when the current is reduced the back e.m.f. produced by the weakening of the magnetic field tries to keep the current going.

The accompanying diagram illustrates the growth of a direct current in an inductive circuit. The practical unit of inductance is the henry (q.v.). See also CHOKE, MUTUAL INDUCTANCE,



In flight, various forces act upon an aircraft, causing lift and what is known as induced drag, here illustrated diagrammatically.

SELF-INDUCTANCE and TIME CONSTANT.

INDUCTION BRAZING, see BRAZING.

INDUCTION COIL. A type of electrical transformer in which the iron core is not closed upon itself. It is usually operated from a D.C. supply, the necessary changes of current being produced by means of a make-and-break contact which may be independently operated, as in the ignition system of a car, or worked by the coil itself on the electric-bell principle. Synonyms: spark coil, Rhumkorff coil. See TRANSFORMER and ELECTRIC BELL.

INDUCTION INSTRUMENTS. Electrical measuring instruments of the type in which a disk is acted upon by two or more magnetic fields which are out of phase. A torque is produced in much the same way as in an induction motor. For single-phase circuits the instrument may employ a phase-splitting device or a shaded pole.

Induction instruments may take the form of ammeters, voltmeters, or wattmeters, but all are suitable for A.C. only. Most A.C. domestic electricity meters work on the induction principle. See SHADED POLE and SPLIT-PHASE.

INDUCTION MOTOR. An electric motor which depends for its operation upon transformer action. Alternating voltages are applied to one winding, normally the stator, and currents are induced in the other, which may be permanently closed (squirrel cage). See MOTOR and SQUIRREL-CAGE MOTOR.

INDUCTION PIPE (Auto. Engineering). The pipe by which the mixture is conveyed from the carburettor of a petrol engine to the inlet ports and valves. The joints between the face of the cylinder ports and the outlet of the induction pipe are sealed by a gasket (q.v.).

INDUCTION REGULATOR. An electrical transformer so constructed that the relative position of the primary and secondary may be varied. It is normally connected to act as a booster, the primary being energized from the supply to be boosted, but a three-phase model may be arranged to give a fixed voltage at a variable phase angle. See BOOSTER.

INDUCTION STROKE. The period of revolution of the crankshaft of a four-stroke internal-combustion engine when the piston is descending and, the inlet valve being open, gases are induced into the cylinder.

INDUCTOR. An electrical circuit component designed to possess inductance. It generally takes the form of a coil of wire with or without an iron core. Synonym: Choke coil. See INDUCTANCE. The term is also used to mean a piece of iron which, by its movement relative to a coil, causes changes in the flux linking the coil so that an e.m.f. is generated therein. See ALTERNATOR.

INDUCTOR GENERATOR, see INDUCTOR.

INDUCTOR LOUDSPEAKER, see LOUDSPEAKER.

INERT CELL. An electric primary cell which remains inactive until water is added to it.

INERTIA. The reluctance of a substance to change its existing state of motion or rest. If, for example, it is desired to move a railway wagon along a perfectly level track, a very great effort is required to overcome its inertia, or reluctance to move. Likewise, once it has been set in motion, almost the same amount of energy is required to stop it, or overcome its inertia.

INFLOW. The increase in velocity which air acquires in front of a propeller of an aircraft; also called inflow velocity. The air which passes through the disk of a propeller is accelerated or speeded up; approximately half of this increase in velocity takes place immediately in front of the propeller and the remainder immediately behind. See OUTFLOW.

INFLUENCE MACHINE. An electrostatic generator, for example, a Wimshurst machine (q.v.).

INFRA-RED RADIANT-HEATING. A term in sheet-metal work which has come to be applied to the method of paint baking in which radiant heat, as opposed to

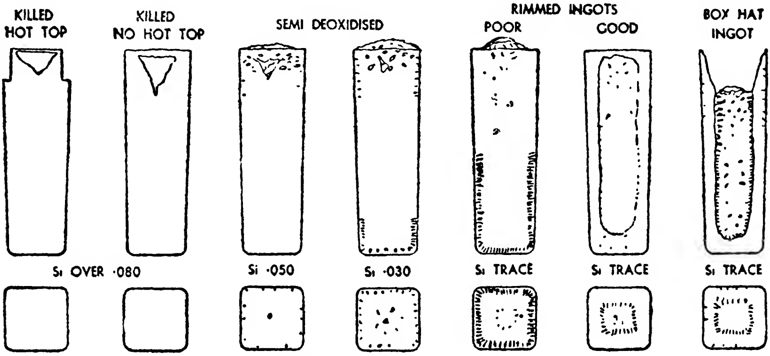
convection, is employed in the stoving of paints and varnishes. Since all radiant-heating is largely due to wave-lengths in the infra-red region of the spectrum, the use of the term "infra-red" in this connexion is redundant.

Radiant heating has enabled the baking of enamels, usually of the oil-based synthetic-resin type, to be carried out from 6 to 10 times faster than is possible in the conventional type of oven. This is due entirely to the greater rapidity with which it is possible to heat the metal by radiation. The process is especially applicable to thin sheet-metal parts where the rate of heating-up can be very rapid.

Tungsten-filament bulbs mounted in suitable reflectors have become one of the best-known methods of applying radiant-heat to metal-finishing processes. This is due to the high efficiency of these bulbs as sources of radiant energy. On account of the difficulty of making adequate use of the convection-heat emitted by the parts being stoved, however, this type of plant tends to be costly to run owing to the small proportion of the electrical energy input which is usefully employed.

It is therefore likely that future developments will tend to favour gas-heated units suitably designed so that maximum uniformity of radiant-heating is obtained from the walls of the oven. Gas-heated installation of this type has the advantages of low initial and running costs, flexibility, simplicity of construction and the possibility of using much higher energy densities than can be obtained with the tungsten filament lamp.

INGOT. A block of metal, either ferrous or non-ferrous, as cast in a mould. Quite often this casting is in the form of an oblong brick with sloping sides. "Ingot iron" and "ingot steel" are terms in general use in the manufacture of iron and steel. Gold and silver are generally handled in this form before being made into coins. Ingots of other metals may be cast in a variety of shapes and sizes as in the case of steel ingots, whose shapes and characteristics are illustrated in the accompanying diagram.



TYPES OF INGOT

Blocks of metal, known as ingots; they are cast in moulds of various shapes and sizes. Characteristics and percentages of silicon content of steel ingots are shown.

INK COVERAGE. The area which can be satisfactorily printed with a standard amount of printing ink. Printing trade customs decree that ink be sold by lb. unit of weight. As the specific gravity of ink varies considerably, inks of the same weight vary widely in bulk. Similarly, variations occur in colour strength or tinting power, in opacity and in working or spreading properties.

Paper also varies widely in the relevant characteristics of smoothness, absorbency and receptivity or print-

ability, in a way which affects ink consumption to a plus or minus degree of 25 per cent.

The following examples of carefully carried out tests indicate, in square inches, the areas covered with the same ink on differently coated papers and different inks on the same paper:-

Black:

Stock A, 157,000; Stock B, 226,800

Yellow:

Stock C, 94,950; Stock B, 158,840

Coated stock B is smoother than coated stock A and C. A demonstration of the better printability of stock B is given by the more economical ink usage. A minimum optimum thickness of ink film is required to cover each type of paper satisfactorily. Should the tinting power of the ink be too great to use the optimum thickness of ink film, the print is unsatisfactory and the ink has then to be reduced with a suitable extender such as tint white or tinting medium to an extent which allows the required bulk of ink to be carried. The thickness of ink film also varies with the printing processes, e.g. direct and offset litho printing. A further factor in both these processes is that a certain minimum ink bulk is required for the different reason of maintaining the balance of ink and water irrespective of the kind of paper being printed.

INLET VALVE (Auto. Engineering). The valve by which the flow of gases from the carburettor into the cylinder of an internal-combustion engine employing spark ignition is controlled and regulated (see VALVES AND VALVE GEAR). In the case of a compression-ignition engine, however, the inlet valve admits air only, a special injector being used for the fuel.

IN-LINE ENGINE. An internal-combustion engine in which the cylinders are placed one behind the other in banks, as opposed to a radial engine, in which they are disposed round the crankshaft like the spokes of a wheel. The most common layouts for in-line engines are four-, six- and eight-cylinder single-bank, and eight- and twelve-cylinder two-bank.

INSPECTION CHAMBER. A bricked shaft, having a sealed cover, to give access to a drainage system for the purpose of inspecting, cleaning or testing. Inspection chambers should be provided at convenient points throughout the system, such as changes of direction or points of connexion of branch drains (Fig. 1), and should be large enough to enable a man to work in them. Suggested sizes for different depths are given below.

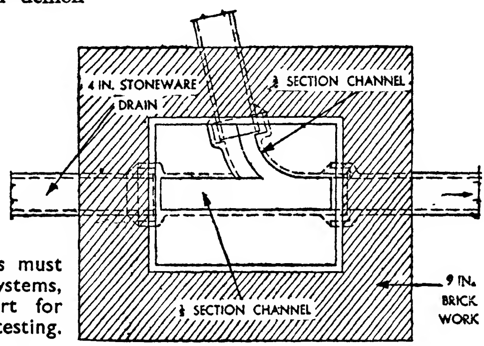


Fig. 1. Inspection chambers must be provided in drainage systems, giving access to each part for purposes of cleaning and testing.

Depth of Drain	Size of Chamber
1ft.0in. to 2ft.6in.	2ft.0in. × 1ft.6in.
3ft.0in. to 4ft.6in.	2ft.6in. × 2ft.0in.
5ft.0in. to 6ft.6in.	3ft.0in. × 2ft.6in.
6ft.6in. to 10ft.0in.	3ft.6in. × 3ft.0in.
10ft.0in. and over	4ft.0in. × 3ft.6in.

The larger and deeper chambers should be reduced at the top to permit the fixing of a standard size cover, and manhole steps must also be provided.

When an inspection chamber is constructed to contain an intercepting trap it is more often spoken of as an intercepting chamber (q.v.). Details of this type are shown in

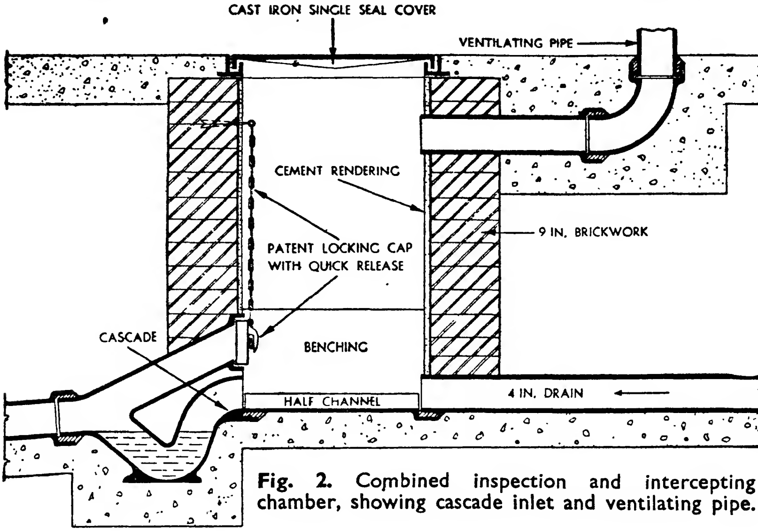


Fig. 2. Combined inspection and intercepting chamber, showing cascade inlet and ventilating pipe.

Fig. 2, from which it will be noted that access to the drain beyond the trap is provided by what is termed the access arm. A quick-release cap is fitted in the end of this arm and held there, usually by a locking bar on a chain.

It will be noted that the stoneware interceptor has a "cascade" inlet, that is to say, there is a drop from the half-channel at the inlet of about 3 in. down to the level of the trap water. This is done to force floating matter through the trap and provide a scouring action.

In the arrangement illustrated (Fig. 2), a ventilating pipe also has been introduced near the top of the inspection chamber and provides ventilation to the house drains and the chamber.

INSTABILITY (Aero. Engineering). An aeroplane is said to suffer from instability if, upon being disturbed from a state of steady motion, it does not return to its original speed and flying position without the assistance of the pilot.

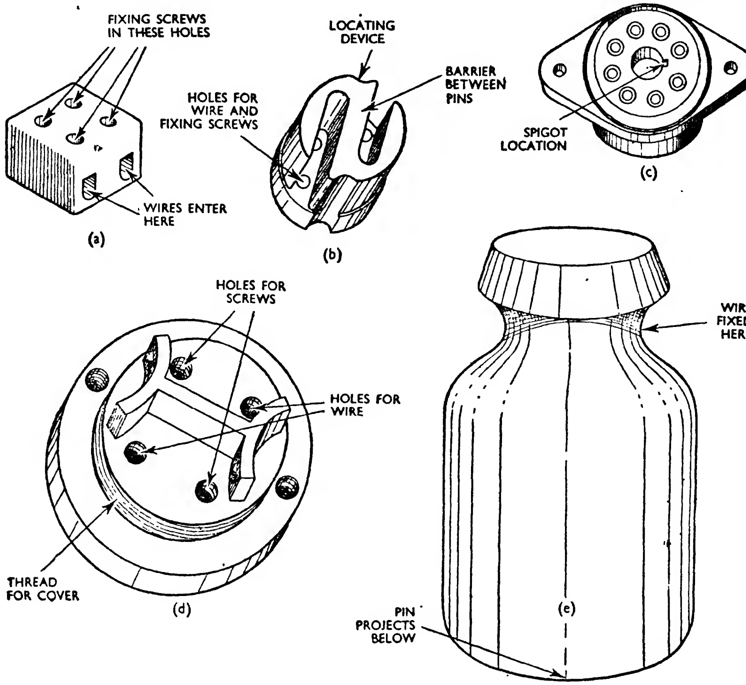
INSTABILITY (Radio). An unstable condition in a radio-valve circuit; a tendency towards self-oscillation. Poor screening, inadequate decoupling, partially exhausted batteries and faulty electrolytic condensers are often causes of this trouble.

INSTRUMENT TRANSFORMER. An electrical transformer designed to produce on its secondary side a current or voltage having a fixed relation to the primary current or voltage both in magnitude and phase. These transformers are used to connect normal measuring instruments or relays to high-voltage or heavy-current circuits. See CURRENT TRANSFORMER and VOLTAGE TRANSFORMER.

INSULATED-RETURN SYSTEM. An electrical supply system in which the earth is not used as a return conductor, as opposed to an earth-return (q.v.) system. In normal distribution practice the terms "earthed system" and "insulated system" are used to mean systems which are or are not connected to earth at one or more points, though both might be regarded as insulated-return systems.

INSULATING MATERIAL, see DIELECTRIC.

INSULATION. A general term applied to the parts of an electrical machine, or other equipment, the purpose of which is to withstand an electric stress or to keep the current



COMMON TYPES OF INSULATOR

Fig. 1. Insulators designed for a number of specific purposes are in general use in electrical engineering. That shown at (a) is utilized to make an insulated joint in two wires; (b) shows the insulator used in an ordinary domestic lampholder; (c) is an octal valveholder; while (d) is the top part of a ceiling rose and (e) a telephone-type pin insulator. It will be noted that, in addition to serving the purpose for which they were designed, insulators often form part of a structure.

within its prescribed paths. A single object of this kind is an insulator and it is made of an insulating material. Some common types of insulator are shown in Fig. 1.

Insulating materials in common use include cotton, silk, enamel, linen, rubber, paper, mica, glass, quartz, porcelain, slate, gases, oil, asbestos, bitumen, plastics and the new synthetic materials. They are divided into classes O, A, B and C according to their ability to withstand high temperatures without deterioration. Class O materials consist of cotton, silk, paper and similar organic materials when used alone. When impregnated, or immersed in oil, they, together with enamel, constitute class A. Mica, asbestos and similar inorganic materials in association with cements and binders form class B, while class C includes mica, used alone, porcelain, glass and quartz.

Cotton, silk, enamel and paper are used for small wires and, with the exception of enamel, for straps, while impregnated paper is widely used for power cables. Linen, in the form of empire cloth and tape, is used for a variety of purposes, such as finishing magnet coils and for windings and end-connexion joints in machines. Paper is made into pressboard, either alone or in conjunction with other materials, and is then used for slot linings and in transformers. Rubber cables are well known, and so is

ebonite, which is a compound of rubber and sulphur, while plastic insulation is to be found everywhere.

Mica has a high dielectric strength and is one of the best materials for withstanding heat. It is used for the insulation of commutators and, in combination with other materials, for slot lining and other purposes. Porcelain is used for transmission-line insulators, covers for bushings and similar purposes. Pyrex glass has also been used in a similar way. A porcelain insulator-string for transmission lines is shown in Fig. 2.

Quartz is valuable for its very high resistivity and slate is easily worked and can be made into pleasing panels for switchboards. Mineral oils are very convenient for use in transformers, switchgear and liquid-cooled apparatus generally. Asbestos is not a very good insulator. It finds application where great heat is encountered, for example, in arc-chutes. It can be made into very satisfactory panel materials when combined with cement and other things. Bitumen is the basis of compounds which are used for filling bus-bar chambers etc., and in

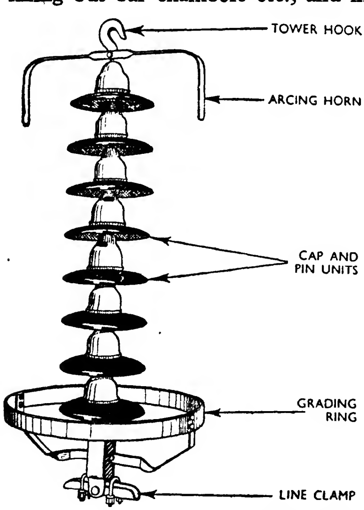


Fig. 2. Type of insulator string used on the grid. Any length of string may be built-up from units. The grading ring is used to reduce the electrical stress in the units nearest the line.

metal-clad apparatus such as ironclad switchgear.

In spite of the choice of materials available, insulation remains one of the most important factors which limit the output of an electrical machine. For high frequencies, other properties than dielectric strength and resistance to heat become important. Dielectric losses, which are negligible at 50 cycles per second, may be so large as to be of vital importance. Dielectric constant (q.v.), and in particular the way in which it changes with temperature, is of importance in the design of condensers for oscillators, while in the case of inductors, a change in the dimensions of the supports, due to a rise in temperature, may cause an appreciable change of inductance. Attention must be given to these points if the frequency of an oscillator used, say, in a superheterodyne radio receiver, is not to drift as the receiver warms up.

To meet these requirements, a number of new materials have been developed, some having one desirable property and some another, some being capable of being formed into any desired shape, while others are limited to simple shapes such as disks, tubes and so on.

INSULATION RESISTANCE. The electrical resistance between two bodies which are insulated from each other. For a single piece of equipment, the insulation resistance is normally a matter of megohms, but where a number of items are connected to the same conductors the insulation resistances are in parallel and the overall insulation resistance may be quite small.

INSULATOR. Basically, a material which, for practical purposes, does not permit the direct passage of an electric current. In radio and electrical work, most conductors must be insulated, either from one another or from earth.

Very special care has to be taken in providing insulators for radio-frequency circuits owing to the fact that the insulator itself automatically becomes the dielectric of a condenser

of which the two plates are the conductors to be insulated from each other. Aerial insulators are usually made of glass, porcelain or glazed ceramic material, as also are lead-in tubes.

Other materials now often used are some of the specially developed plastics, which not only prevent direct current leakage, but also do not give rise to serious dielectric losses at high frequencies. At very high frequencies, all solid insulation should be kept to a minimum and air-spaced separation of conductors arranged wherever possible.

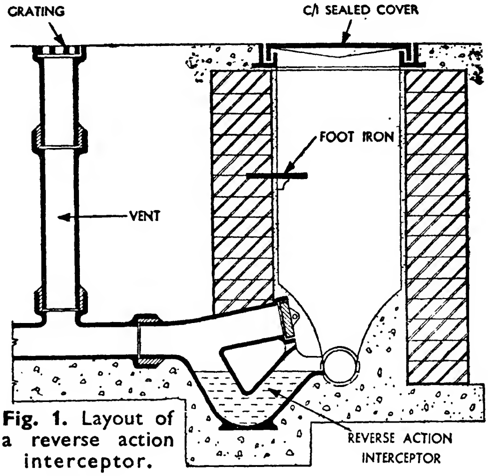
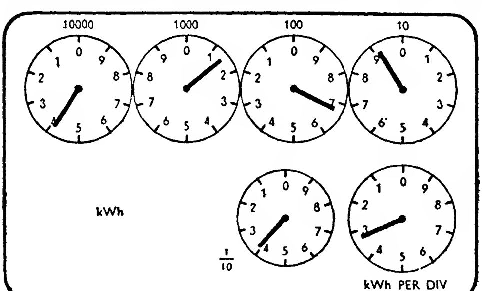


Fig. 1. Layout of a reverse action interceptor.

INTEGRATING WATTMETER. An electricity meter, usually so constructed that its speed is proportional to power and fitted with a mechanism for counting the revolutions. The indication of the total number of revolutions is given on a dial arranged to read in kilowatt hours. A form of dial commonly used on domestic meters is shown in the diagram. Synonym: Watt-hour meter. See WATT-HOUR.



Dials of this electric-supply meter are calibrated to read in kilowatt hours or units. Successive pointers usually rotate in opposite directions, so that the reading shown is 41,693.4 kWh. The numbers 10,000, 1000 etc. above the dials indicate the kWh per division.

INTERATOMIC DISTANCES. The distance between the nuclei of two adjoining atoms in a solid chemical compound. It can often be measured by X-ray analysis or electron diffraction. The distance between the nucleus of a chlorine atom and that of an adjoining sodium atom in a crystal of common salt is 2·81 Ångström units.

In organic compounds the interatomic distance between two carbon atoms varies from one compound to another. In the diamond and in the paraffins it is 1.54Å, while in graphite it is 1.42Å; in benzene it is 1.39Å and in acetylene it is 1.20Å. In other compounds various intermediate values are found, indicating that fractional values of valency are in operation.

INTERCEPTING CHAMBER. A manhole, or access chamber, situated at the lowest point of a drainage system and nearest to the main sewer. Normally, the chamber is fitted with an intercepting trap to disconnect the house drain from the main sewer, as illustrated under the heading: INSPECTION CHAMBER. The object of this trap is to prevent the transference of

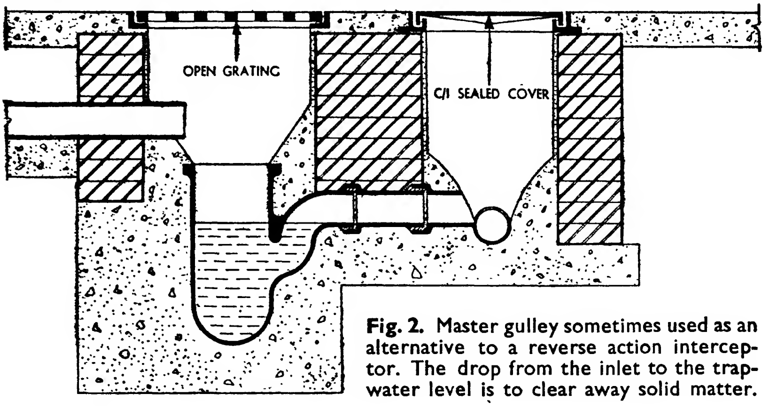


Fig. 2. Master gulley sometimes used as an alternative to a reverse action interceptor. The drop from the inlet to the trap-water level is to clear away solid matter.

gases from the sewer to the drains and possibly into the building.

To disconnect the rain and surface water drains from the foul water drains a reverse action interceptor (Fig. 1) may be used or, alternatively, a master gulley as shown in Fig. 2.

The intercepting chamber should be as near as possible to the sewer and in line with the drainage system, and its depth will to some extent govern the depth at which the drain is laid. The trap should have a water seal of at least 2½ in. and should be constructed, if possible, with a cascade inlet with a sharp drop of from 2 to 3 in. down to the water level. The object of the drop is to force floating material through the trap and provide a scouring action.

INTERCONNECTOR. An untapped electrical power line or cable between two supply points or between two distributing centres.

INTERCONNECTED STAR-CONNEXION, see ZIG-ZAG CONNEXION.

INTERCOOLER. A cooler or radiator, placed between the stages of a multi-stage supercharger to reduce the temperature of the air or fuel-air mixture entering the cylinders of an internal-combustion engine. The term is also sometimes applied to a cooler which is placed between the supercharger and the engine, though this should more properly be called an "after-cooler". The heat may be carried away from the inter-cooler either by a suitable flow of air directed through it, or by a fluid circulated through a radiator exposed to the air flow.

There is a limit to the temperature at which the mixture may be fed to the cylinders, for above a certain figure, dependent on the type of cylinder, detonation will be caused. When a supercharger is operating at a high compression ratio, such as can be obtained with a two-stage supercharger, the rise in temperature of the mixture passing through it is very great, so that the temperature at which detonation takes place may be exceeded; hence it is necessary to fit an intercooler to reduce the temperature to the required figure. As an intercooler reduces the temperature of the air or mixture, it increases the density of the charge in the cylinder, so that the power that the engine develops at a given number of revolutions per minute and a given amount of boost increases with the increase in the amount of cooling.

INTERCRYSTALLINE CORROSION. The gradual wearing away, due to chemical attack, along the boundaries of individual crystal grains of which steel is composed. This is a type of attack from which the 18 per cent chromium/8 per cent nickel and similar types of austenitic stainless steel are prone to suffer, unless the composition is so adjusted that it will provide an effectual safeguard.

This adjustment of composition may take the form of reducing the carbon content of the steel to such an extent that the material is nearly carbon-free, but the safer and more general procedure is to make an addition of a "stabilizing" element, the elements employed in this connexion being titanium and columbium.

While intercrystalline corrosion may take place without any marked change in the appearance of the steel, any subsequent application of stress may result in brittle fracture of the steel or even, in extreme cases, in complete disintegration. The internal structural condition which renders ordinary 18 per cent chromium/8 per cent nickel steels liable to this trouble is produced by exposure to a temperature of the order of 500 to 800 deg. C., and in practice this may be applied by heating the steel to such a temperature, or by cooling the steel (from a higher temperature) through this range of temperature at an insufficiently rapid rate.

Welding operations invariably result in some portion of the steel being reheated to a temperature within this critical range; in the case of butt-welds on sheet material, this zone occurs in the sheet material parallel to the actual weld and distant from it by, say, ¼in. In the case of "unstabilized" 18 per cent chromium/8 per cent nickel steels, this zone is susceptible to intercrystalline corrosion and, after exposure to severe corroding media, may disintegrate on the application of any stress. This feature has given rise to the description "weld decay", although the failure occurs adjacent to, rather than in, the actual weld. An actual weld may, of course, be affected if a second weld crosses it.

INTERFERENCE (Aero. Engineering). The difference between the drag of two or more component parts of an aircraft when assembled, and the sum of their individual drags when tested separately. It has been found from wind-tunnel tests that the drag of two parts of an aeroplane, say the wing and the fuselage, is greater when they are tested together than the sum of their drags when tested separately, and any number of component parts can be involved. This phenomenon has been confirmed on full-scale aircraft.

INTERFERENCE (Radio). The effect produced in a radio receiver by an unwanted signal being received simultaneously with the desired

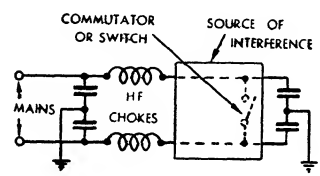


Fig. 1. Interference caused by a sparking commutator or faulty switch may be minimized by the method shown.

station. Three methods of suppressing interference are shown in the diagrams. Interference may be of several types and due to many causes. That known as *atmospherics* (q.v.), or static, is caused by natural phenomena and does not indicate a receiver fault. It can be very troublesome on broadcast wavebands during thunder or

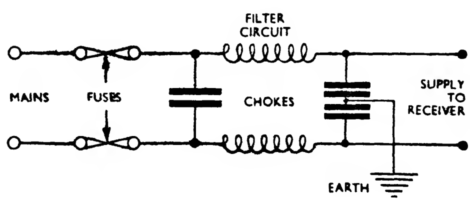
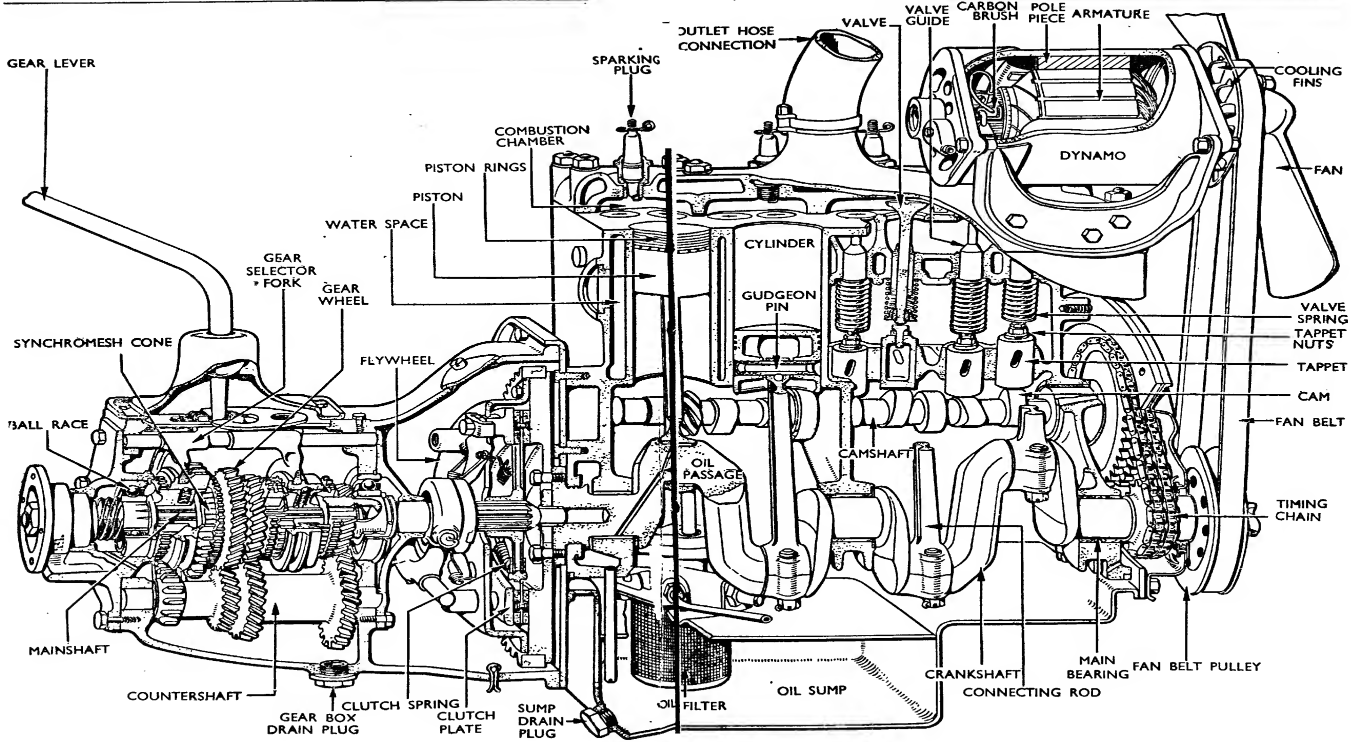


Fig. 2. Filter circuit placed between supply mains and receiver to suppress mains-borne interference.

electrical storms, and is caused by lightning discharges between clouds and between clouds and earth. The characteristic sound is a series of loud "crackles," possibly completely drowning the programme for an



CONSTRUCTIONAL DETAILS OF A POWER UNIT

Part-sectional view of the power unit, clutch and gearbox as fitted to an Austin Eight. It will be seen that this engine is of the side-valve type, a special chain and sprockets being used for driving the camshaft at half-engine speed. A belt from the pulley on the end of the crankshaft drives the fan mounted on the dynamo.

on the induction stroke, the fuel being injected under pressure a fraction before the piston has reached top dead-centre.

Two types of injection are employed: (1) solid or airless injection and (2) air-spray injection. In (2) the fuel oil is forced into the cylinder head by a jet of air at higher pressure than that within the cylinder, and in (1) the fuel is injected by means of a pump, the effective length of the stroke determining the amount of the charge. The pump stroke is constant; control of engine speed is effected by allowing the charge to leak away through a spill port at a predetermined moment.

Various types of cylinder head are employed to give a swirling, or mixing, motion to the air. Some of these are illustrated in Fig. 1. Modern design, however, tends to use an ante-chamber as the true combustion chamber, and, in an engine of this type, when the piston is at the top of its stroke, there is practically no space between the top of the piston and the cylinder head, the compressed air being forced along a narrow channel into the separate combustion chamber. This forcing of the charge into such a small, compact space, assisted by the angle at which the connecting passage is placed, causes great turbulence, so that the fuel is rapidly atomized, or broken up, and distributed throughout the whole volume of air.

The semi-Diesel engine—a name sometimes wrongly applied to those heavy-oil engines which draw in their supply of vaporized fuel and air mixed—has a hot bulb or wire in the cylinder head to assist or inaugurate combustion. This means that a lower compression ratio can be used, as ignition is not entirely dependent on the heat of compression. Both Diesel and semi-Diesel engines can be built as single- or double-acting; i.e. fuel can be admitted to one side only of the piston, or to both sides as required. The single-acting two-stroke semi-Diesel has been much favoured for marine work, sometimes with the addition of a scavenger pump to help in clearing away exhaust gases.

Starting from cold may be a difficulty with the compression-ignition engine, and various methods have been developed to overcome the high compression ratios. One method consists of lowering the compression, by means of a decompressor, to a point at which it is possible to rotate the engine sufficiently for starting. In one form, the decompressor moves the camshaft endwise so that a special cam operates the exhaust valve, opening it for a fraction of the compression stroke to release some of the charge and pressure.

Another form of decompressor opens a passage from the cylinder leading to a decompression chamber so that there is an increase in the volume of the space into which the charge is compressed. To overcome the reduction in temperature in these cases, a heater for starting is installed in the cylinder head; on modern engines this somewhat resembles a sparking plug, save that instead of a spark gap, heating coils are provided. This device is shown in Fig. 2. Other forms of starting involve the use of compressed air stored in bottles filled either from an auxiliary or the main engine.

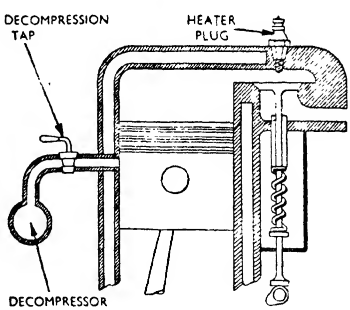


Fig. 2. Decompression device, with heater plug, for use on Diesel engines.

The method of cooling gas, oil and compression-ignition engines is usually the same as for petrol engines, i.e. by water and radiator. Successful compression-ignition engines for air-

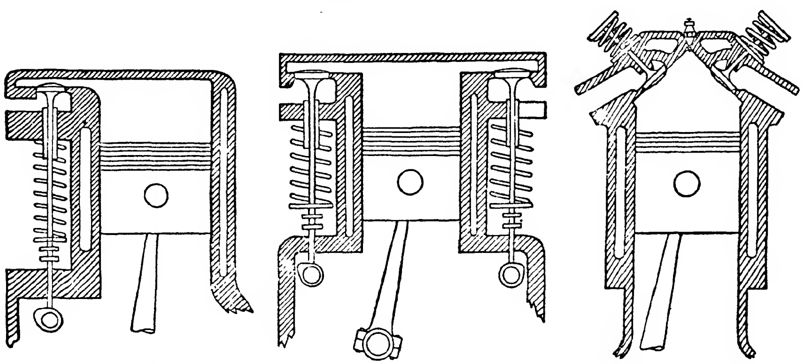
craft use have, however, been made, using finned cylinders and air as the cooling medium. Tank-and-hopper cooling is frequently used on stationary engines, sometimes, with very large engines, a number of cooling tanks being connected.

Generally speaking, the petrol (constant volume) engine is a lighter and higher-speed unit than the Diesel (constant pressure) type. Such engines are spark-ignited and burn the lighter spirits obtained from the distillation of petroleum or from other sources. They are further distinguished from the compression-ignition type by the fact that both air and fuel are drawn into the cylinder as a mixture before compression. This means that there is a definite limit to the compression ratio that can be used, a ratio of between 5 and 6 to 1 being all that is possible with normal fuel, while not more than 7 or 8 to 1 is possible, without detonation even with doped fuel. Detonation is the too-sudden explosion of the fuel, caused mainly by a too-high compression for the fuel used, but is also influenced by the shape of the cylinder head, the speed at which the engine is working and other factors.

Some general types of cylinder head, fitted with the ordinary poppet valves, either overhead or at the side, are shown in Fig. 3. The sleeve valve, for which much smoother running is claimed when fitted to high class engines, takes the form of a cylindrical sleeve, open at both ends, which is fitted inside the engine cylinder, the piston being free to move inside the sleeve.

The sleeve is connected direct to the camshaft by a small sleeve connecting-rod, which causes it to slide up and down a small distance sufficient to allow the ports, cut in its sides, to register with the inlet and exhaust ports in the cylinder itself. In single-sleeve engines, rotary as well as axial motion is imparted to the sleeve to enable the ports to register. Double-sleeve-valve engines have two sleeves, one within the other, the piston operating in the innermost sleeve. This system has, however, largely given way to the single-sleeve type.

Another type of valve is the rotary, illustrated in Fig. 4. Valves of this type enable extremely high speeds to be attained, as there is a definite limit to the speed at which a poppet valve can be made to lift up and down. Rotary valves are in the form of a drum or disk having holes which register with corresponding ports in the cylinder head, and are usually



GENERAL TYPES OF CYLINDER HEAD

Fig. 3. In L-type cylinder heads, both valves are placed on the same side of the piston; in the T-type, valves are situated one on either side; while overhead valves, as their name implies, are fitted in the head itself, with the stems upwards.

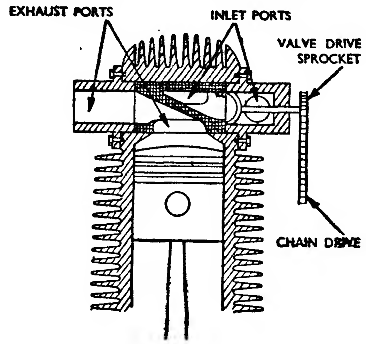
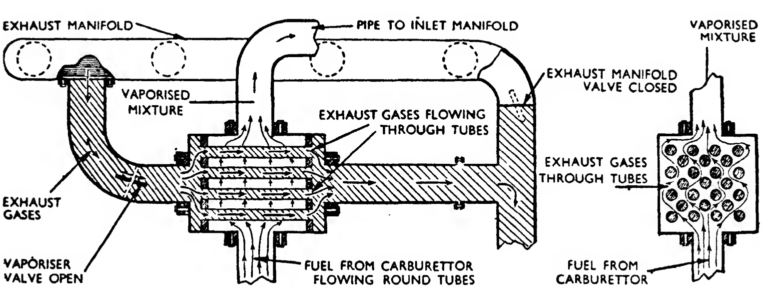


Fig. 4 (above). Diagram showing main components of a rotary-valve engine.

chamber divided into a series of compartments, through one set of which the fuel passes, and through another set of which the heating medium passes. They can be of either the tube type or plate type. A tube-type vaporizer is shown in section at Fig. 5.

The exhaust gases pass through the tubes from an exhaust manifold by-pass at the same time as the fuel oil is being drawn by engine suction round the spaces between them. The vaporizer is mounted in the induction pipe between the carburettor and the engine. A paraffin engine, therefore, must either be run for a few moments



TUBE-TYPE VAPORIZER

Fig. 5. Side view (left) and end view (right) of a vaporizer of the tube type. As fuel oil will not readily vaporize at atmospheric pressures and temperatures, it must be heated to a point at which it can be ignited on reaching the cylinders.

driven by a chain direct from the crankshaft.

Where fuels, such as paraffin, which do not vaporize easily at atmospheric pressure and temperature, are used, a vaporizer is necessary. This usually takes the form of a simple carburettor, heated either by the hot water from the cylinder jackets or by exhaust gases from the cylinder. A vaporizer consists of a

on petrol to warm it up, or some means must be taken to heat the vaporizer instead.

Gas engines are used mainly as

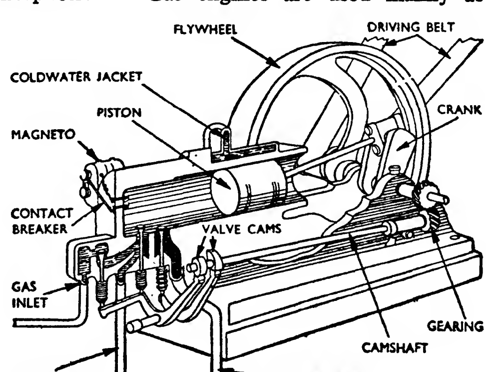


Fig. 6. Fuel used in gas engines may be either coal gas or producer gas.

stationary power plants. They follow the same general principles as the oil-fuel type, save that, of course, no carburettor or vaporizer is needed. A typical gas engine of the horizontal type is illustrated at Fig. 6. Gas engines burn coal gas or producer gas, and can be fired either by an electric spark or by a hot tube.

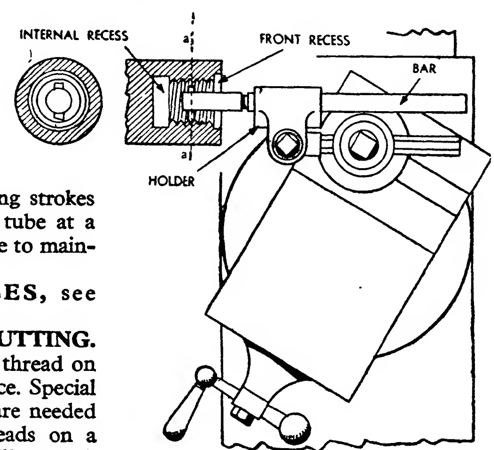
In the latter method a tube of special metal is screwed into a hole in the cylinder head. When starting the engine, this tube is first heated by a gas jet or blowlamp, so that when the crankshaft is rotated and the gas and air are compressed, the heat of the tube is sufficient to ignite the mixture and set the engine running. Once it has warmed up, the heating flame for the tube may often be removed, the heat of the firing strokes being adequate to keep the tube at a sufficiently high temperature to maintain combustion.

INTERNAL STRESSES, see STRESS.

INTERNAL THREAD-CUTTING. The machining of a screw thread on an internal cylindrical surface. Special measures and precautions are needed when cutting internal threads on a lathe, which process is illustrated. The best results are of course obtained when the operation can be finished with a tap, but often no suitable tap is available and it is then a good plan, if the workpiece is of an awkward shape or of considerable weight, to make a gauge by cutting a corresponding external thread on a short length of circular material.

Generally it is found necessary to bore the hole to a definite diameter before beginning to cut the thread. This ensures a bore that is true and of the correct size. If the hole is blind, and the thread cannot be cut all the way through, it will be necessary to machine a recess at the end of it; the recess must be at least as deep as the thread and of somewhat greater width, so that the screwed portion can run into it. The provision of side rake on the thread tool will make the thread-cutting easier and will give better results.

Springiness of the tool is particularly undesirable, so the tool-holder should be as massive—short and thick—as the dimensions of the thread will allow. The setting of the thread tool should be such that the cutting point is on the horizontal centre-line of the work. A small front recess or shoulder may be bored before the actual thread-cutting begins, to serve as a guide to the depth of the thread.



Set-up of slide rest for the internal thread-cutting process on a lathe. On the left is shown a plan view of the cutting tool through section a—a.

Internal thread-cutting involves the movement of the cross slide towards the operator during the actual cut, and away from him before reversing. The first cut will be simply a broad line, which becomes wider and wider as the operation nears its finish; but because of this increase in width, the feed must be correspondingly diminished, in order that the rate of metal removal may be approximately constant. It is important when working in steel to have a copious supply of cutting oil.

INTERNAL-THREAD MICROMETER. An instrument used in checking internal threads for any

variation from true circular form, or to search for possible high spots. It is simply a variety of plug gauge provided with four expanding jaws. The jaws can be moved either towards, or away from, the centre by an adjusting screw which causes them to slide against a tapered centre piece, somewhat similar to the action of an expanding mandrel.

Each jaw has its outer edge machined to the profile of the thread to be checked, but before being used the instrument itself is tested by checking it against a ring on which a master-thread is cut. The jaws can of course be used only for one particular thread size, and must be changed if other sizes of thread are to be checked.

Having inserted the micrometer in the thread to be measured, the operator adjusts the jaws by screwing a milled nut until all jaws are just touching the thread. A graduated scale on the stem of the micrometer enables the exact size to be read off. By rotating the micrometer through various angles, and taking a further reading in each fresh position, the location of high spots, if any, can be ascertained.

INTERNATIONAL POWER. The maximum power and r.p.m. at which an aero engine is allowed to operate for protracted periods. On British engines this corresponds to the climb rating and on U.S. civil engines it is the maximum for both climb and level flight.

INTERNATIONAL R.P.M., see INTERNATIONAL POWER.

INTERNATIONAL UNITS OF ELECTRICITY. The following units are in general use to-day:

Ohm. The resistance offered to a direct current by a column of mercury at the temperature of melting ice, 14·4521 grams in mass, of constant cross-sectional area and of a length of 106·3 cm.

Ampere. The direct current which deposits silver at the rate of 0·001118 gram per sec. when passed through a solution of nitrate of silver in water, prepared to a standard specification.

Volt. The electromotive force between the terminals of a conductor having a resistance of 1 international ohm in which a current of one international ampere is flowing.

Watt. The energy expended per second by an unvarying electric current of one ampere under an electric pressure of 1 volt.

INTERPOLE. Synonym for COMMUTATING POLE (q.v.).

INTERRUPTED CONTINUOUS WAVE (I.C.W.). A radio-frequency carrier wave interrupted, i.e. stopped and started, at an audio frequency and used in radio-telegraphy signalling. Its chief advantage is that it can be received without apparatus involving the heterodyne method of reception.

INTERRUPTER GEAR. Electric or hydraulic mechanism used when machine guns are fitted to an aeroplane so that they fire through the propeller disk. The interrupter gear prevents the gun from being fired when the propeller blades are in the line of fire.

INTERSTAR CONNEXION, see ZIG-ZAG CONNEXION.

INTERSTITIAL COMPOUNDS. Compounds with holes or interstices in the structure that may be wholly or partially filled by groups of atoms forming a part of the compound. The compounds have therefore no definite chemical composition, only an approximate one. Palladium hydride, some of the metallic carbides and nitrides, red lead and white lead appear to be interstitial compounds.

INTRINSIC BRILLIANCY. The apparent candle power per unit projected area of a source of light. See CANDLE POWER.

INULIN, see CARBOHYDRATES.

INVAR. An alloy of iron with about 35·5 per cent nickel, 0·5 per cent carbon, and 0·5 per cent manganese. It has so low a coefficient of expansion that a rod of invar remains practically the same length at all temperatures between about 50 and 400 deg. F. It has been used in the manufacture of clocks and measuring tapes.

INVERTED ENGINE. An aircraft engine in which the cylinders are

placed below the crankshaft. The use of this design does not in any way affect the functioning of the engine and in practice is sometimes found to be more convenient as it provides a better field of vision from the cockpit of a single-engined aeroplane.

INVOLUTE GEAR TEETH. A system of gear-wheel teeth in which the mathematical curve known as the involute is employed to form the tooth profile. An involute may be traced experimentally by winding a piece of string around a drum placed over a sheet of paper, the string having a small loop at the free end as shown in the illustration. By inserting a pencil into the loop and then unwinding the string, keeping the latter

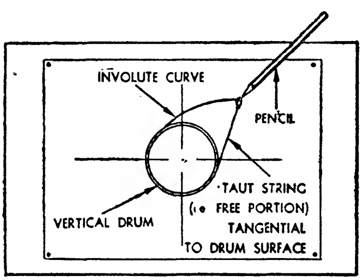


Diagram showing method of tracing involute curve using a pencil in a loop of string round a vertical drum.

taut, an involute can be traced-out on the paper.

At any given moment the free portion of the string makes a tangent with the surface of the drum. This system of gearing is generally used in preference to the cycloidal system because the gears will mesh correctly even if there are fairly wide deviations from the correct centre distance between the gear-wheels. In spite of such deviations, the relative velocities of two involute gear-wheels in mesh will not be altered.

When used for racks and pinions, certain variations may be introduced; thus the rack tooth may have the points rounded so as to obviate interference, although theoretically the tooth should, as usual, be straight-sided.

IODINE (I). Atomic no. 53; atomic wt. 126·92; an element which occurs in sea-water and may be obtained from the ashes of seaweeds; its principal source, however, is the mother liquor of crude sodium nitrate in Chile; density 4·95, m.p. 113·5 deg. C., b.p. 184·4 deg. C. It is a crystalline, blackish non-metal, chemically similar to chlorine and bromine. It sublimes on heating, giving off a deep-violet vapour. It is heptavalent, trivalent, or monovalent. It dissolves readily in a solution of potassium iodide, KI, and in alcohol.

An alcoholic solution of iodine and potassium iodide, known as tincture of iodine, is used medicinally as a germicide and for other purposes. Among the compounds of iodine are hydriodic acid, HI, and iodoform, CHI_3, formerly very largely used as an antiseptic dressing but now superseded by other drugs. Unsaturated fats and fatty acids, containing carbon atoms connected by a double bond, absorb iodine, and the amount of the iodine absorbed is a measure of the degree of unsaturation, and is known as the iodine value.

ION. A term used to denote an atom, or group of atoms, which has lost or gained one or more electrons. Solid metals and salts are not assemblies of disconnected atoms or molecules. A rod of copper consists of ions of copper held together by the attraction of groups of electrons. A crystal of common salt consists of alternate ions of sodium and chlorine held together by electrical attraction.

Other solids, e.g. fibres, do not consist of ions, but of groups of uncharged molecules. When a salt is dissolved in water the constituent ions fall apart and move freely through the solution; the same is true of the hydrogen ions in an acid solution. See ATOM, ELECTROLYTE, ELECTROLYSIS and ELEMENT.

IONIZATION OF WATER. Though consisting in the main of separate molecules of H_2O, water is to a small extent ionized into charged ions, hydrogen H, and hydroxyl OH. There are present 10^{-7} gram-ions of

each species per litre of water, which is expressed by saying that the P_H of the water is 7.

When an acid, say HCl, is added to the water, more H ions are released into the solution. Some of these recombine with free OH ions to form water, and the concentration of OH ions is lowered. The result is that there is now a great excess of H ions, which is what is meant by saying the solution is acid.

If the concentration of H ions is now 10^{-3}, the concentration of OH ions will have been lowered to 10^{-11}, so that the product $10^{-3} \times 10^{-11}$ is maintained at $10^{-14} = 10^{-7} \times 10^{-7}$. The P_H of the solution is now 3.

IONOSPHERE. That part of the atmosphere above approximately 50 miles from the earth's surface forming what corresponds to a conducting shell surrounding the earth. It consists of electrified, or ionized, layers and confirms a theory put forward by Heaviside in England, and by Kennelly in America, to explain the behaviour of certain radio waves.

At least two major layers exist, as well as several subsidiaries, and are known as the Heaviside layer, or E-layer, and the Appleton layer, or F-layer, these being named after their discoverers. The Heaviside layer is some 60 miles and the Appleton layer about 140 miles above the earth's surface. They are both formed by the ionizing action of the sun's radiation. The condition of the ionosphere, which varies with the time of day and season of the year, has a very important effect on the propagation of radio waves over long distances. See RADIO-WAVE PROPAGATION.

IRIDIUM (Ir). Atomic no. 77; atomic wt. 193·1; a hard white metal of the platinum group, density 22·4, m.p. 2350 deg. C.; forms an alloy with osmium called osmiridium. It is usually trivalent or divalent, but in some compounds is pentavalent or hexavalent.

I^2R LOSS. Synonym for COPPER LOSS (q.v.).

IRON (Fe). Atomic no. 26; atomic wt. 55·85; density 7·87; m.p. 1530 deg. C.; b.p. 2950 deg. C.; a grey metal, with exceptional magnetic properties, found in abundance in most sandstones and volcanic rocks. It is usually obtained in the state of metal by reducing oxide by coke and limestone in a blast furnace; the molten metal is run into pigs.

Pig-iron can be melted and cast; it is then known as cast-iron (q.v.) and contains about 2·5 to 4 per cent carbon and small quantities of silicon, phosphorus and sulphur. It is too brittle for many purposes and is therefore converted into wrought-iron by reheating with haematite iron-ore in a puddling furnace. Wrought-iron, which melts at about 1500 deg. C., is malleable, but cannot be cast. A malleable cast-iron can be made by packing white-iron castings in powdered red haematite and heating in an annealing oven for a few days. A considerable quantity of cast-iron is made into steel.

Iron is a mixture of four isotopes, the principal one having a mass of 56; it forms two main classes of compound: ferrous, of which ferrous sulphate, $FeSO_4$, is an example; and ferric, an example of this class being $Fe_2 (SO4)_3$.

Many of the compounds of iron are of importance. Haematite is a common iron-ore, chiefly consisting of ferric oxide, Fe_2O_3. The ferroso-ferric oxide, Fe_3O_4, is magnetic oxide of iron or magnetite. Ferrous carbonate, $FeCO_3$, occurs in natural state as spathic iron-ore and as siderite. Ferrous sulphate, $FeSO_47H_2O$, also known as green vitriol and copperas, is the raw material for the manufacture of many compounds of iron, and is used in medicine when mixed with magnesium sulphate and quinine.

The common mineral iron-pyrites is a disulphide, FeS_2, largely used in the manufacture of sulphuric acid. A complex cyanide of iron and potassium, potassium ferrocyanide, has the formula $K_4[Fe(CN)_6]3H_2O$, and is known as yellow prussiate of potash. From it is made the pigment Prussian blue (q.v.), a ferrocyanide of iron sometimes containing potassium

ferrocyanide. Iron dissolves carbon and combines with it. Carbide of iron, cementite, Fe_3C, plays an important part in alloy steels. Iron combines with carbon monoxide to form carbonyls, e.g., $Fe(CO)_5$ and $Fe(CO)_9$.

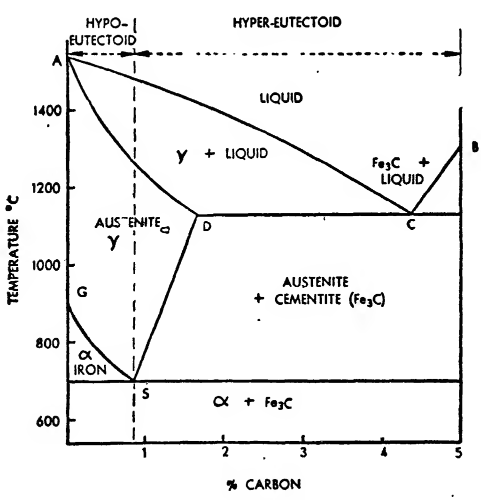
The physical properties of iron depend on its temperature; up to about 700 deg. C. iron exists as alpha-iron, and is strongly magnetic; at about 800 deg. C it exists as beta-iron, with a different specific heat and electrical resistance; beta-iron is non-magnetic; at about 920 deg. C. it changes into gamma-iron, and this changes into delta-iron at about 1400 deg. C.

IRON-CARBON ALLOYS. The equilibrium diagram for the iron-carbon system is shown in the accompanying diagram which has been simplified intentionally, but the alteration is only of importance in considering the alloys of low-carbon content. As will be seen, iron containing up to 1·7 per cent carbon will solidify completely in the form of austenite (or γ phase), a solid solution of carbon in iron.

Iron containing between 1·7 and 4·3 per cent carbon will consist of a eutectic of austenite and cementite (Fe_3C) in addition to primary austenite crystals. Above 4·3 per cent carbon cementite separates first, followed by the austenite-cementite eutectic. The diagram may, for convenience, be divided into three parts, 0·0 to 0·87 per cent, 0·87 to 1·7 per cent and 1·7 to 4·3 per cent carbon respectively. Commercial alloys rarely contain more than 4·3 per cent carbon.

The alloys containing 0·0 to 0·87 per cent, on cooling below the line *GS*, deposit α iron, containing a minute proportion of carbon, and finally a eutectoid of iron (ferrite) and cementite, known as pearlite, as indicated by the point *S*. Between 0·87 and 1·7 per cent carbon, the solubility of carbon in austenite is reduced as shown by the line *DS*. The final structure, therefore, consists of free cementite and pearlite. These two carbon ranges cover most of the steels available commercially. Above 1.7 per cent carbon, the amount of austenite decreases as the temperature falls from 1100 to 700 deg. C. owing to the partial decomposition into cementite; while at 700 deg. C. the remaining austenite transforms into the eutectoid pearlite. This range of carbon covers white cast-iron and a few exceptional steels.

There is some evidence to suggest that the diagram, as given, represents only a metastable condition and not true equilibrium. For example, high carbon steels deposit free graphite on prolonged annealing. It is said that in true equilibrium a eutectoid of austenite and graphite is first produced. This is certainly true of grey cast-irons containing silicon—a pronounced graphitizer. With this modification the diagram gives a reasonable explanation of the struc-



Equilibrium diagram for iron-carbon alloys.

ture of such irons which may consist of ferrite, graphite and pearlite; pearlite and graphite only; or pearlite, cementite and graphite.

In addition to primary graphite produced in the eutectic, secondary graphite is deposited owing to the decreasing solubility of carbon in austenite along the line *DS*.

IRON LOSS. The power loss in an electrical machine or circuit component which is due to the subjection of iron or similar material to a varying magnetic field. It consists of two parts; the hysteresis loss and the eddy-current loss. The total loss in a normal sample of electrical laminations is of the order of ⅜ watt per lb. at 50 cycles per second and a flux-density of 10,000 gauss. See EDDY CURRENT and MAGNETIC HYSTERESIS.

IRONWOOD. A name generally applied to very hard and heavy woods, difficult to work. There are about 100 species which come from different parts of the world. The best known are Pyinkado, Mesquite, Ipil, Ekki, Billian and Gangau.

ISINGLASS (Painting). A very pure colourless gelatin (q.v.) made from the air bladders of the sturgeon. It is mainly used as a fixative for gilding upon glass, but also serves as a protective coating upon other types of gilding. In combination with a little fullers' earth it is used as a film upon oil-painted decoration to obtain uniform matt finish; when the murals become dirty this can be easily removed with warm water and replaced for further protection. See GILDING.

ISOLATOR. An electrical switch or link intended for operation only when the circuit is already dead. It may be used to isolate a piece of equipment for such purposes as inspection, cleaning, or testing.

ISOMERISM. A term describing the existence of two distinct chemical compounds, each having the same number of the same atoms in its molecule, but arranged differently in space. Thus, ammonium cyanate, NH_4CNO, and urea, $(NH_2)_2CO$, are isomers. So also the compounds $CH_3.CH_2.CH_2Cl$ and $CH_3.CHCl.CH_3$ are isomers.

Some isomers readily change from one form to another, and the two varieties are mixed together so that they can hardly be separated. This state of affairs is called *tautomerism.* A very important kind of isomerism is optical isomerism, due to asymmetry; one molecule has exactly the same groups and atoms as the other, and neither molecule is symmetrical in the arrangement of its groups and atoms, but one bears to the other the same relationship as a hand bears to its image in a mirror.

Such asymmetric molecules rotate polarized light either to the right or to the left, and in general both varieties can be prepared; thus, there is one variety of tartaric acid that rotates polarized light to the right and another variety that rotates it to the left. A similar existence of two varieties of the same compound is found in many kinds of sugar.

ISOMORPHISM, See CRYSTALS.

JACK. A device, often portable, for raising heavy loads through a short distance. The common types in general use by motorists consist of either a threaded spindle raised by a nut rotated by hand gear, or a small hydraulic ram operated by a pump worked with a short lever. In the case of the former, rotation of the screw nut causes the threaded spindle to rise out of its housing, thereby raising the weight resting on it. In order to obtain maximum lift this type of jack (Fig. 1) is sometimes constructed with one threaded spindle inside another. When the outer screw reaches the end of its travel the next comes into operation, thus continuing the raising movement.

Jacks working on the hydraulic principle have a central chamber containing the lifting ram. Into this

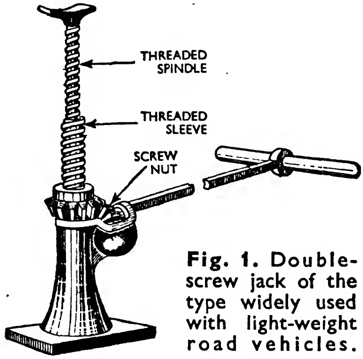
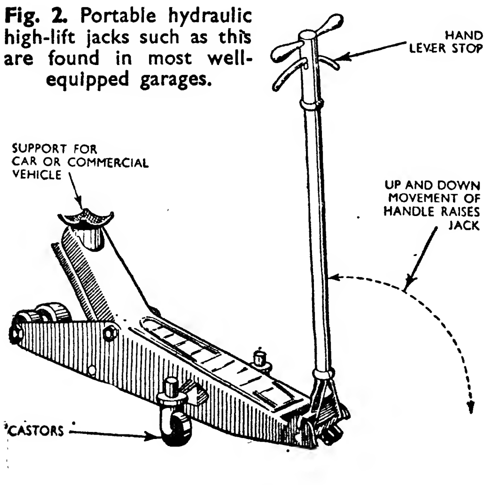


Fig. 1. Double-screw jack of the type widely used with light-weight road vehicles.

chamber a fluid is pumped by hand to raise the ram. A release valve is provided to lower the ram, when desired, by allowing the fluid to flow back into the first chamber.

Either of the foregoing types gives satisfactory service to the motorist and, since they are comparatively small, have the additional advantage of being easily stowed away on the vehicle. For heavier work, such as in garages and workshops, however, more robust types are in general use. A popular design is the high-lift type (Fig. 2). These jacks have the advantage of being portable even when carrying the load. The various operations are controlled by the handle, which also serves as a means of moving the jack from one place to another.

Fig. 2. Portable hydraulic high-lift jacks such as this are found in most well-equipped garages.



A valuable permanent fixture at large garages is the hydraulic lift which consists of a platform at ground level, capable of accommodating the vehicle and of being raised several feet to enable work to be performed more easily underneath the vehicle. It is customary in this type of lift for the platform to be raised by compressed air pumped into the central column, a release valve being provided for lowering the platform as and when desired.

JACK RAFTERS, see Roofs.

JAMB. The side of a window or door opening, or the surface which connects the two faces of a wall. *Chimney jambs* are the sides of a fireplace opening, usually formed by allowing the brickwork to project into the room. *Jamb stones* are the stones forming the vertical surfaces at the sides of a door and window opening. A *jamb lining* is the woodwork used for covering the brick jambs of door and window openings.

JAPAN GILDING, see Gilding.

JAPANNERS' GOLD-SIZE. A clear, transparent oil-varnish containing driers (q.v.) suitable for use as an adhesive material for gold and other metals in leaf form, bronze, flock etc.; also as an ingredient in paints made from pigments ground in turpentine and in filling compositions. It is of two varieties: "quick", which becomes surface dry in one hour and hard dry in four hours; "slow", which dries to a gilding tack in not less than two hours and retains that tack for not less than ten hours.

JAR. A unit of electrical capacitance. It is equal to $\frac{1}{900}$ of a microfarad.

JARRAH, see Eucalyptus.

JET PROPULSION. A form of aircraft propulsion in which the motive power is derived from a jet, or jets, of gas ejected rearwards at high velocity. This is similar to rocket propulsion, though a rocket

does not consume air in burning its charge. It is, therefore, difficult to produce a rocket which will burn long enough to be suitable for aircraft propulsion purposes.

Jet propulsion schemes for aircraft, many of which have been patented, usually comprise a compressor similar to an aero engine supercharger, which feeds air to one or more combustion chambers into which liquid fuel such as petrol or paraffin is injected. The fuel and air mix and burn in the combustion chamber, and the hot gases are ejected rearwards at high speed through a nozzle. In some schemes the compressor is driven by a conventional aero-engine, while in others the combustion gases pass through a turbine wheel before they are ejected, and the power produced by the turbine is used to drive the compressor. The first reported case of successful flight by a jet-propelled aircraft was that of the Italian Caproni-Campini machine in 1940. Early in 1944, great prominence was given in the British press to successful experiments with a machine of this type designed by Air Commodore Frank Whittle, R.A.F., from which the Gloster and the Meteor developed, the latter achieving a speed of over 616 m.p.h. in September, 1946. See ATHODYD.

JIG. A device designed to aid the accurate machining of parts, especially in repetition work for mass-production. It is a special tool which gives the correct fixing and location of a workpiece during actual machining and is consequently equipped with apparatus for guiding and setting the actual cutting tools so that all parts manufactured with the help of a particular jig shall be exactly similar.

Fixtures are generally classed with jigs. The difference, broadly, is that a jig holds the work (or is clamped to it) and is also provided with guides for the tools doing the actual machining; a fixture merely holds the work without having any means for guiding the tools; it may, however, carry several gauges and stops which, in turn, control the action of the tools.

Hence jigs are especially useful on drilling and boring machines, whilst fixtures find wide application in milling, and occasionally shaping, machines. Special jig-boring machines have been developed for this work; these are provided with means for setting both spindle and worktable and for locating the holes accurately without the necessity for making exact measurements. Thus the worktable may have horizontal length-wise adjustment, while the vertical spindle has adjustment in a lateral direction at right-angles to the other direction of adjustment. Lead screws with micrometer dials are sometimes incorporated to enable accurate measurements of the settings to be made; or, alternatively, vernier scales may be fitted.

Use in Metal Work

In sheet-metal work the advantages of jigs and fixtures are that (a) they maintain dimensional accuracy during forming, (b) they increase production rate, (c) they enable comparatively unskilled labour to deal with quite complicated assemblies in clearly defined ways and (d) they assist standardization. All such fixtures are designed to place and hold parts in position for such operations as are necessary (riveting, drilling etc.), but if work is to be welded it is also necessary to allow for heat expansion and, sometimes, dissipation. When jig-assembled or formed units are to be used later in building-up sub-assemblies, they will have been gauged to size automatically and an easy fit is thereby assured.

The main points to remember when jig planning are: (1) the precise work to be done—is simple holding enough, or do one or more extra factors require attention? (2) all locating points should be pre-determined, and, if possible, left in the clear view of the operator; (3) operation of the jig should be easy and speedy, and it should be impossible to place work out of position; (4) the design that is simplest, most secure and speediest will generally be found to be most practical and satisfactory in service.

JOB INKS. Types of ink used for the large bulk of general printed work; also on normal papers as used for bookwork, stationery and general commercial printing. They should not dry on the rollers, but printed work should be dry in about 10 hours.

Black pigments form roughly 25 per cent of the weight of the ink, the balance containing a percentage of hard gums. Almost any colour may be obtained, but as the specific gravity of the coloured pigments varies widely, so does the volume of the different coloured inks. Job inks are usually made in stiffer consistency for the platen than for the cylinder press.

JOCKEY WHEEL, see IDLE WHEEL.

JOGGLE (Building). The shouldered portion which is formed on a structural member to take the weight or thrust from another member. It is also the term applied to a binding piece, similar in effect to a dowel, which pins together two adjacent stones in masonry. A joggle of the latter type appears in the illustration to be found under the heading FLASHING.

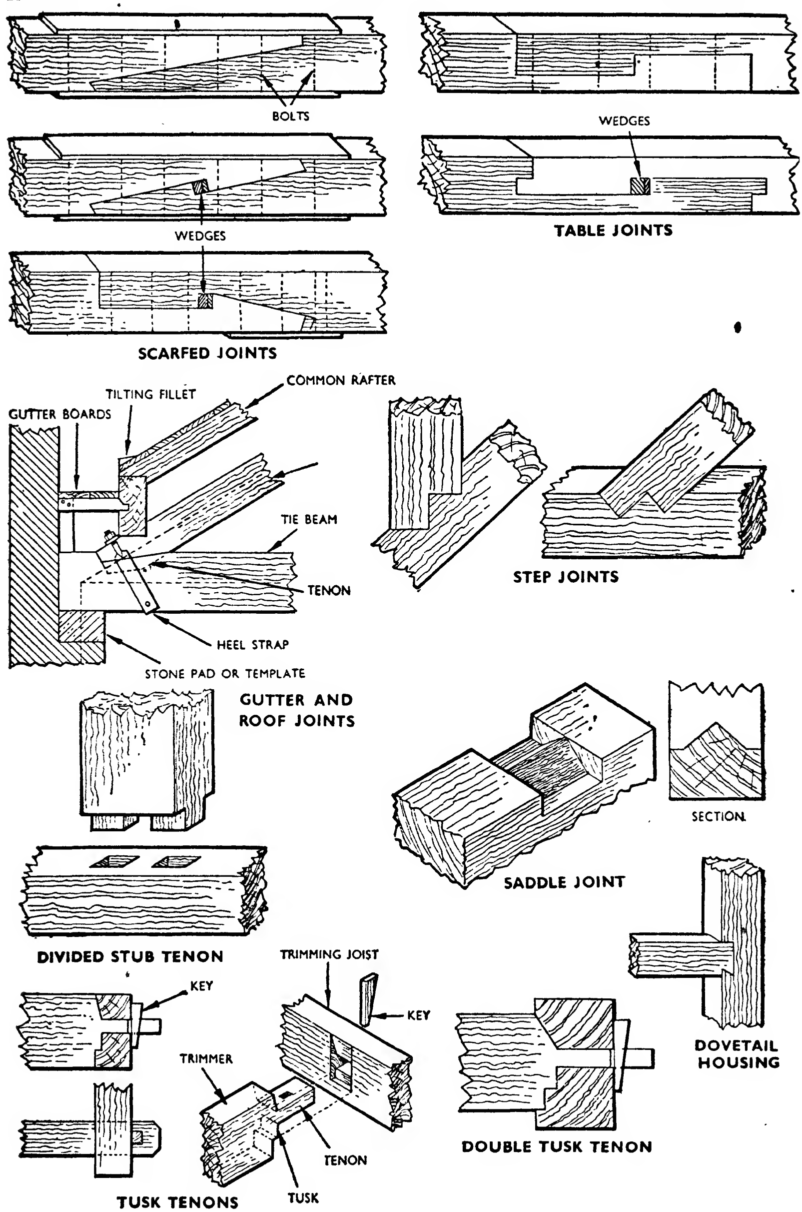
JOINTLESS FLOORING. A floor-covering, usually applied to the top surface of concrete floor slabs, and taking the place of floor boards. The material may be described as a composition of magnesium chloride and magnesium oxide. The mixture is spread over the screeded surface and, when hard, results in a durable and hygienic floor surface. Skirtings are usually made of the same material and are continuous with the floor.

JOINTS (Carpentry and Joinery). Of the many different types of joint, several are common to both constructional and finishing work in building. *Angle* joints, for timbers not in the same plane or straight line, comprise a large group which includes bridle, cogging, dovetailing, halving, housing, keying, mitring and mortise-and-tenon joints. *Lengthening* joints, which are chiefly concerned with carpentry, include halved, fished, lapped, spliced, scarfed and tabled joints. *Joinery* joints for building-up widths include tongue-and-groove, dowelling, secret and slot-screwing etc; hinging and shutting joints are used in doors and casements.

The important consideration in constructional work is strength, whereas appearance is often more vital in joinery. Carpentry joints, therefore, are designed to resist bearing, tension, compression and shear. The resistance to these forces should be equal to obtain the maximum efficiency. Other important factors are accuracy and simplicity, as the work is often framed under adverse conditions and with heavy unseasoned timber. Many intricate joints are sound in theory but bad in practice. The following points should be considered: surfaces under pressure at right-angles to pressure, best arrangement of grain, possibility of shrinkage and size of abutting surfaces which resist the thrust. There are many variations and combinations of the joints illustrated, and many of them depend upon metal fastenings for their efficiency, e.g. nails, screws, bolts, straps and timber connectors. This applies especially to constructional and external work. Glue is usually the most effective in joinery joints.

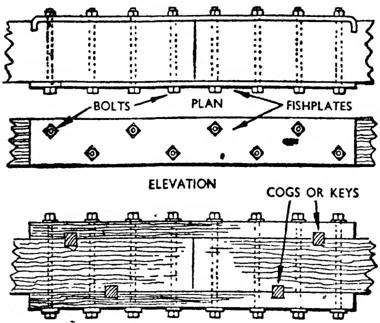
The joints for lengthening heavy constructional timbers, without increasing the sectional area, are known as *scarfed* joints. There are several variations shown in Fig. 1. When the scarfings are parallel to the edges they are also known as *table* joints. If they are strengthened by iron or wood plates they are called *fished* joints. The joints are bolted together and the bolts must be staggered. Hardwood keys or folding wedges are often used to force the ends into contact. The proportions shown are only approximate, and every case must be designed according to its position in the structure and the load it has to carry.

ROOF TIMBERS. There are many joints peculiar to roof trusses and framed partitions. The *bridle* joint is used at the foot of a principal rafter or post. It is a form of reverse

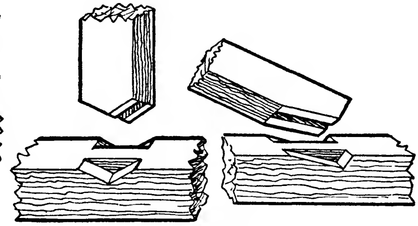


JOINTS AND FASTENINGS USED IN

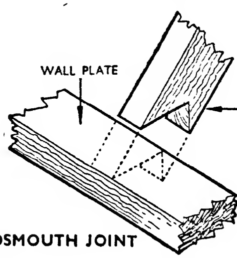
Fig. 1. In all constructional work the most vital factor to be borne in mind is strength, whereas the appearance of the finished structure is of only secondary importance. It therefore follows that joints intended for use in structural



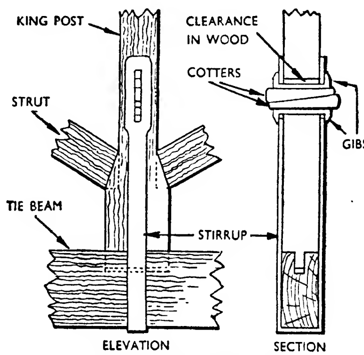
FISHED JOINTS



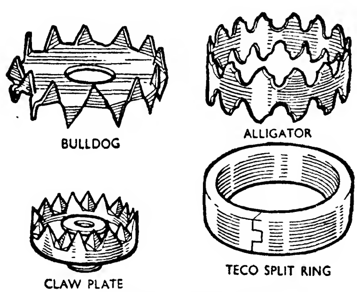
BRIDLE JOINTS



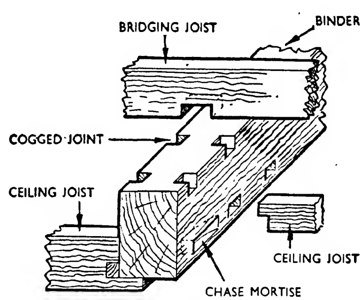
BIRDSMOUTH JOINT



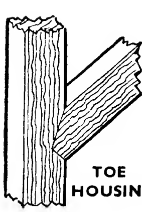
GIB AND COTTER JOINTS



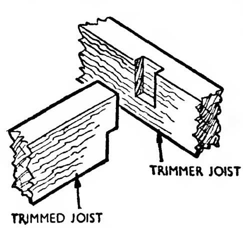
TIMBER CONNECTORS



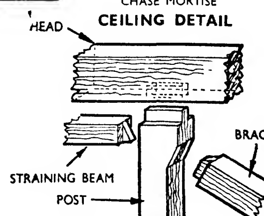
CEILING DETAIL



TOE HOUSING



TRIMMER HOUSING



PARTITION DETAIL

CONSTRUCTIONAL WORK WITH WOOD

framing are designed to give the greatest resistance possible to tension, compression, shear and other forces. Simplicity and ease in construction are, however, essential as the work has frequently to be carried out under adverse conditions.

tenon and is an alternative to the *housed-and-tenoned* joint shown in "gutter and roof joints". The *step* joint is another alternative, but this is used in heavy structural work, such as spectators' stands, bridges etc., rather than in roof trusses. It provides the maximum resistance against thrust without unduly weakening the supporting member. The feet of common rafters, at the eaves of a roof, usually have a *bird's-mouth* joint. A king post is fixed to the tie beam by a bolt up the centre, straps and bolts, or by means of a *gib and cotter* joint. The cotters, or folding wedges, tighten up the joint, whilst the gibs provide a seating for the cotters, and hold the straps in position. The precaution when framing this joint is to provide the necessary clearance, or draw. Several examples are shown of the *stub tenon*, which is the type used in constructional work for struts and posts as shown in the partition detail. It is an ordinary mortise-and-tenon joint, but the tenon enters only a small distance into the mortised member. The *saddle* joint is an alternative and is very effective for preventing lateral movement and for providing a large surface to receive the pressure.

Metal Fastenings

TIMBER CONNECTORS. Metal fastenings have become very popular for constructional timbers in recent years. They prevent lateral movement against the forces acting on the joint, and simplify the arrangement of straps and bolts. There are several patent types. The *bulldog* is a circular or rectangular plate with the serrated edges turned up and down in the form of sharp prongs. These bite into the wood round the bolt and prevent movement against tension, compression, or shear. The *alligator* acts in a similar way, but this is in the form of a corrugated ring with sharpened serrated edges. The *Teco* requires a prepared groove rather larger than the internal diameter of the split ring, and the spring in the steel ring prevents movement of the joint. There are several other patented types such as the claw plate, spike grid, shear plate etc. See ROOFS.

FLOOR JOINTS. The chief joints used in framed floors are: mortise-and-tenon, cogged, housed, forked and tusk tenon. The *cogged* joint prevents lateral movement where one horizontal timber supports another, as between joists and binder. The recess to receive the supported timber is called a *notch*. There are several variations of the mortise-and-tenon. A simple type is the barefaced stub tenon between ceiling joist and binder. It is so called because it is shouldered on one side only. When the ceiling joists are between two binders, one end is driven in sideways by means of a *chase mortise*. The *tusk tenon* is very important when trimming an opening in a floor. The joint is a combination of *housing* and *tenon* joints, for bearing-timbers at right-angles to each other. It is used between trimming joist and trimmer. The tenon may be as shown, or placed centrally on the neutral axis, but it is better in the compression area. The housing may be from $\frac{1}{4}$ to $\frac{1}{3}$ the thickness. A double-tusk tenon is used when the supported timber is narrower than the supporting timber. Another use of the *housing* joint is when the end of one joist is let into the side of a supporting joist. The housing should only be above the neutral axis (see FLOORING).

The joints used in the finishings and fitments of buildings are more varied than in constructional work.

HALVING JOINTS. These are the simplest joints for joining two pieces at right-angles, or lengthways, in the same plane and with flush faces. There are several variations, such as the dovetailed and bevelled halvings.

ANGLE JOINTS. Fig. 2 overleaf shows seven different methods of jointing "with the grain". The *butt* joint is the most common, but both the *rebated* and the *tongued* joints are better as they prevent movement when assembled. The second group shows several forms of secret joints. The mitred joint requires blocks glued

in the corner unless the joint is glued. The rebate and mitre, or lipped mitre, is a good secret joint. The *lipped mitre and dovetail* is used for the end of a rail fixed to the solid end of the carcase of a cupboard etc. This is shown by the graining of the wood. *Housing* joints. Two examples of housing shelf-ends are shown. The dovetail housing, if stopped about ⅛ in. from the front edge of the uprights, makes a good secret joint.

JOINTS IN THE SAME PLANE. The most important joint in building up the width of wide surfaces is the glued *butt joint*. The edges must be square and straight for a good joint (see GLUE). A butt joint may be strengthened by *dowels*, although the dowel joint may be used in any direction of the grain and is often used in place of a mortise-and-tenon. The dowel should be split from hardwood, and shaped by driving it through a dowel plate. The plate has holes of different diameters. A groove should be run down the dowel to allow air and glue to escape.

SECRET SCREWING. This is another method of strengthening a butt joint in good-class work. The screws project from one piece, and corresponding holes are bored for the heads in the other piece, about ½ in. in advance of the final position. Slots are then made to take the shanks of the screws. The pieces are put together, and the piece with the screws is tapped until the ends of the pieces are level. The piece is then knocked back, the screws tightened a little, to ensure a tight joint, both pieces are glued and then finally assembled.

TONGUE AND GROOVE. The joints for flooring and matchboarding are: butt, loose tongue, tongue and groove and vee, tongue and groove and bead, rebate, rebate and fillet, and tongued joints for secret nailing. Loose tongues are usually of plywood. The vees and beads are used in matching to break the joints and to hide shrinkage.

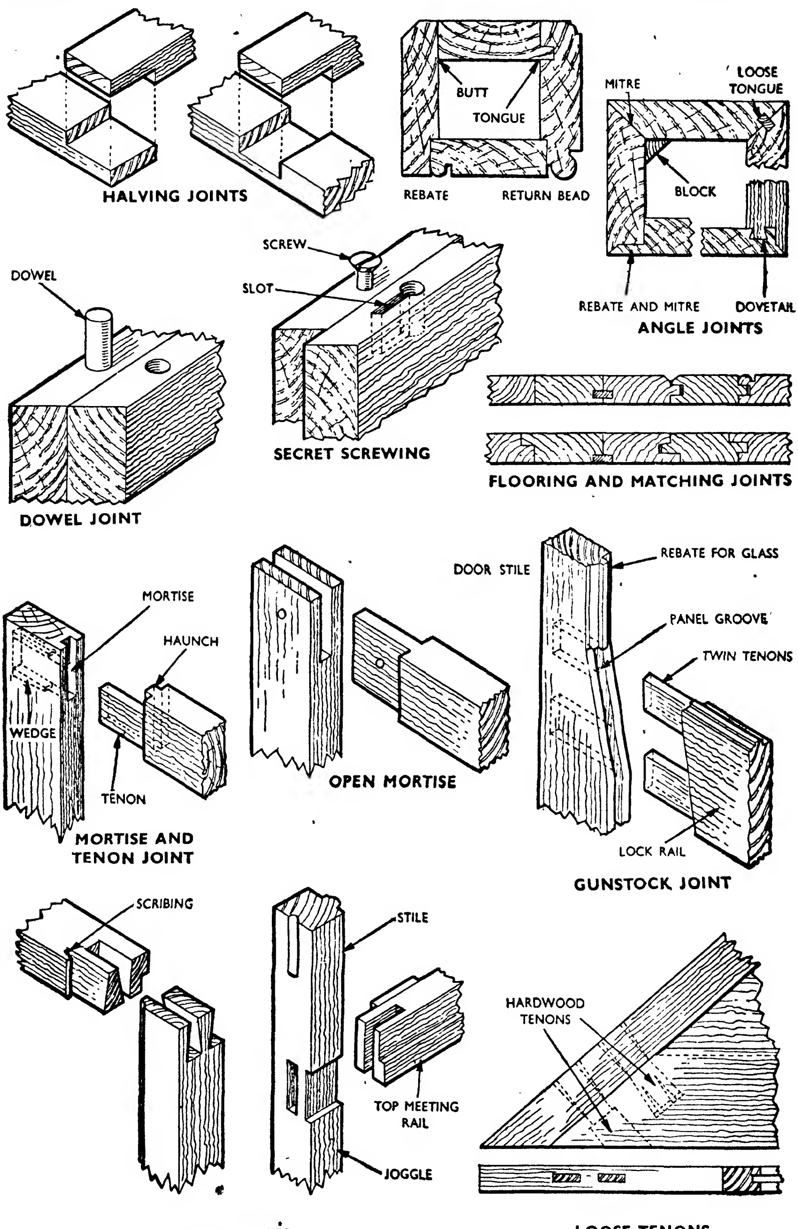
COUNTER BATTENS. For wide, built-up surfaces, not fixed to joists or studs, it is necessary to fix battens on the back. The battens should allow for free movement with change of moisture content. Three examples are shown that fulfil these conditions. For counter tops the *buttons* are best. These are fixed to the top by a single screw, so that the buttons can engage with the rebates on the batten, or with the carcase supporting the top. The *slot-screw* is another good method. The slot holds the head of the screw and leaves the tail of the screw free to move with the boards. The *dovetailed batten* is difficult to fit and is seldom used.

Doors and Windows

MORTISE-AND-TENON. There is a variety of these joints used in doors, sashes, frames etc. The first example shown is used between the end of a stile and a top rail. It is necessary to reduce the width of the tenon for wedging, and a small part is left for the haunch to prevent the rail from twisting. An *open mortise* is used when wedging is not required, and the joint is held by a pin, or dowel. The width of a wedged tenon should be from three to five times the thickness, and the thickness should be one-third of the thickness of the mortised piece. The *gunstock joint*, for a lock rail, is used where the top part of the door is glazed. Three other forms of joints for middle rails are shown. The *double tenons* are to allow for fixing a mortise lock. They can be used only in thick doors. The *barefaced* tenons are used on framed-and-ledged and batten doors (see DOORS).

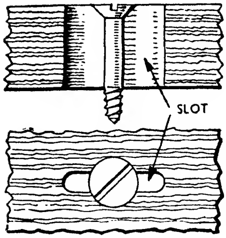
SASH JOINTS. These vary from the haunched tenons. The projection is reversed and forms part of the mortise, and a corresponding recess is cut in the end of the rail. This is often called franking. The illustration shows two methods for the meeting rails of sliding sashes. The joggle increases the strength and the joint is easier to make than the dovetail (see WINDOWS).

LOOSE TENONS. These are used for the acute angle of spandril framing, as

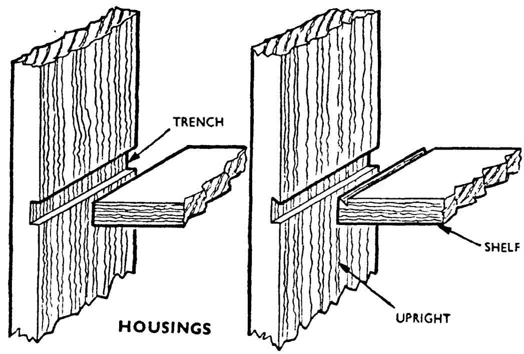


JOINTS FOR FITMENTS

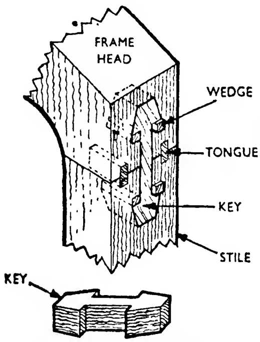
Fig. 2. For fitments and finishings in buildings, there is an even wider variety of joints than those used in general constructional work and each joint has its specific purpose and application. The method of forming these joints is shown



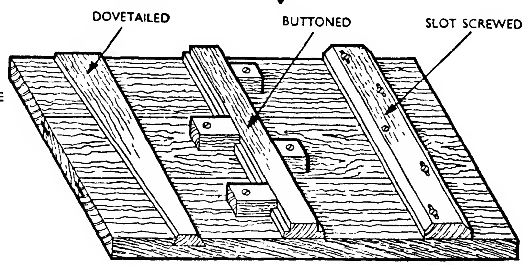
SLOT SCREWING



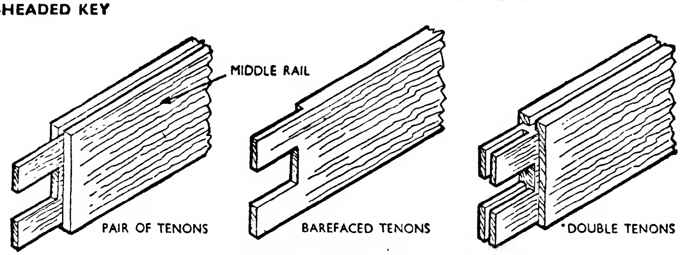
HOUSINGS



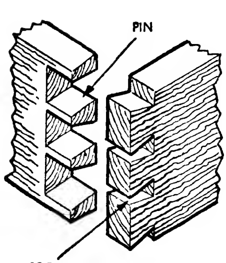
HAMMER-HEADED KEY



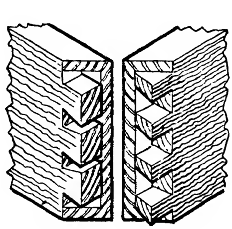
COUNTER BATTENS



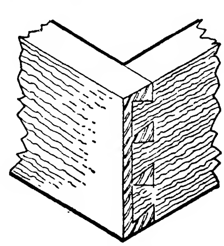
TENONS FOR DOORS



COMMON DOVETAIL



SECRET DOVETAIL



LAPPED DOVETAIL

AND FINISHING IN BUILDING

and the uses for which they have been designed are explained in the text. In all cases, accuracy is, of course, a vital factor in the construction of a strong joint, more consideration being given here to the appearance of the finished article.

under a flight of stairs, or in circular work of small radii. They should be of hardwood.

HAMMER-HEAD KEY. This joint is used to join a circular head to the stile of a door or frame. The key is sometimes formed on the stile, especially when of hardwood. The loose tongues are to prevent the joint from twisting.

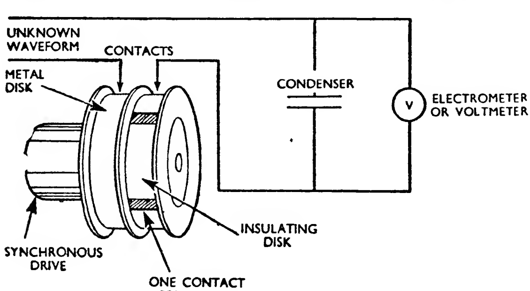
DOVETAIL JOINTS. Three examples of dovetailing are shown, but there are many variations. It is the best form of joint for two pieces end to end and at right-angles to each other. The *common* dovetail is used where strength is of first importance. The *secret* dovetail is used only in first-class work where the end grain must be hidden. It is a difficult joint to make, and has the appearance of a mitred joint when assembled. The third case is a compromise used for drawer fronts, where the end grain is covered by the carcase. When making the common dovetail it is better to make the pins first if there are only one or two joints to make. When the pins are prepared they are marked round on to the socket piece and then the sockets are sawn and chiselled out. If a number of similar joints are to be made it is quicker to make the sockets first. In this case about six of the socket pieces are nailed together and the eyes removed in one operation. Dovetailing can be done on special machines, but the usual machine joint consists of rectangular pins in close formation, and is called corner-locking.

j OPERATOR. A mathematical device used to assist in electrical-circuit calculations. As an example of its use, an impedance consisting of a 10-ohm resistor in series with a coil having 8 ohms reactance and no resistance can be written as $10+j8$ ohms. See IMPEDANCE.

JOISTS. Timber beams used in the construction of floors in domestic and temporary types of building. They are laid in parallel rows, from 12 in. to 16 in. apart centre to centre, and support the floor finishings. The ends of the timber joists are usually supported upon timber wall-plates (q.v.), which rest upon the brickwork. They are laid in whichever direction is most suitable in regard to length, so as to economize in timber.

In the construction of ground floors, intermediate support is obtained by building sleeper walls (q.v.) from the surface layer up to the under side of the joists. In upper-floor construction, however, intermediate support cannot be obtained and therefore the safe limit of span is 16 ft. The depth of the joists in inches can be determined by halving the span in feet and adding two for domestic buildings.

JOUBERT CONTACT. An electro-mechanical device used for plotting waveforms, point by point. The accompanying diagram shows the arrangement. The disk is either mounted on an alternator shaft or driven synchronously with the waveform to be investigated. See ALTERNATING CURRENT and OSCILLOGRAPH.



Once per cycle, the condenser in this circuit is connected to the unknown waveform and charges up to the voltage at that instant. By moving the contacts round, the voltage at each point in the cycle may be found.

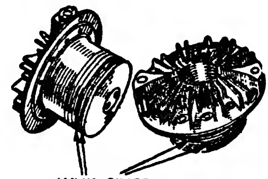
JOULE. Symbol: J. A practical unit of electrical energy. If energy is consumed at a rate of one joule per second, the rate of working is one watt (q.v.).

JOULE EFFECT. The production of heat in a conducting

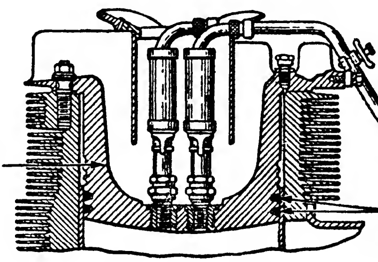
body when an electric current is passed through it. See COPPER LOSS.

JOULE'S EQUIVALENT. The amount of work that can be converted into one calorie of heat; it is equal to $4{\cdot}17 \times 10^7$ ergs.

JOULE'S LAW. The law of the electrical production of heat by the Joule effect (q.v.). This states that the amount of heat is proportional to the product of current squared, resistance and time.



Above, two views of a junk head; below, enlarged sectional view of a head fitted to sleeve-valve engine.



JOURNAL. That part of a shaft lying within a bearing.

JOVIGNOT METHOD, see CUPPING TEST.

JOYSTICK, see CONTROL COLUMN.

JUNK HEAD. A component of a sleeve-valve engine which, as shown in the illustration, is comparable to the cylinder head of a conventional engine. Its centre portion projects down into the cylinder with a space between it and the cylinder walls in which the top end of the sleeve is located. The junk ring is a form of piston ring preserving a gas-tight joint between the junk head and sleeve.

JURY STRUT. A strut inserted to give temporary support to a structure, usually in a biplane. See BIPLANE.

KARRI, see EUCALYPTUS.

KEEBUSH. A strong, tough, acid-resisting plastic loaded with mineral matter and used for the storage of acid liquors and for a variety of plant exposed to acid fumes.

KEENE'S CEMENT. A type of hard wall plaster consisting of hard burnt gypsum (calcium sulphate) to which an accelerator has been added, used for situations where a hard, compact surface is required. It is slow-setting and must be used without the addition of slaked lime. If it is to be painted with oil paint it is primed as soon as the surface will stand the passage of the brush applying the paint. See HARD WALL PLASTERS.

KEEPER. A piece of iron or similar material used to complete the magnetic circuit of a permanent magnet, or magnets, to prevent loss of magnetization when the magnet is not in use. See PERMANENT MAGNET.

KELVIN'S LAW. The law, relating to the cost of electric cables, which states that the least total cost per year is obtained when the cost of losses for the year is equal to the annual cost of that part of the capital expenditure which is proportional to the current. The size of a conductor so determined may not be the best from other points of view, for example, voltage drop.

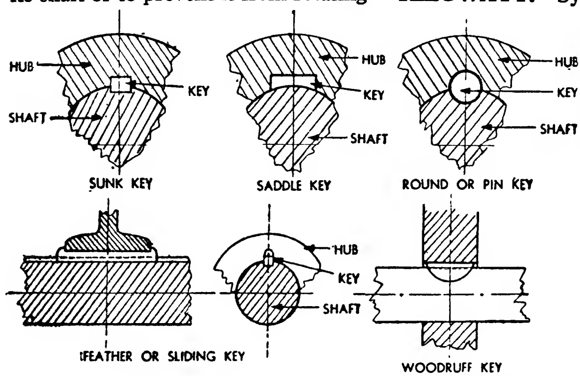
KENNELLY-HEAVISIDE LAYER, see IONOSPHERE.

KERR CELL. A device at one time used in television to modulate a light beam at high (video) frequencies. It consists essentially of two electrodes in nitrobenzene.

KEY (Elec. Engineering). A hand-operated electric switch used to transmit messages telegraphically by a

code consisting of combinations of impulses. This type of key is usually spring-loaded to facilitate operation.

KEY (Mech. Engineering). A locking piece used in machine work, chiefly to ensure that a certain component (e.g., a pulley or crank) rotates with its shaft or to prevent it from rotating



Keys, or locking pieces, are used on various machines to prevent relative motion between a hub and shaft. Types in general use are shown with their respective applications.

relatively to the shaft. Keys, usually of square or rectangular steel bar, are fitted into either a key-way or key-seat, generally machined or cut partly in the shaft and partly in the component to be secured.

There are numerous forms of key, some of which are shown in the diagram. *Sunk* keys are accommodated partly in a groove in the hub of the gear or pulley, partly in a slot in the shaft. *Saddle* keys, which conform to the shaft profile and rely upon frictional grip alone, are slightly tapered longitudinally so as to provide a driving fit. A *round* or *pin* key is one which fits into a round hole drilled partly in the shaft and partly in the pulley or gear. A *feather* key or *spline* is a key along which a pulley or gear-wheel hub can slide laterally. A *Woodruff* key consists of a portion of a disk, the curved edge fitting into a corresponding longitudinal groove in the shaft.

KEYING, see JOINTS.

KILOCYCLE. Symbol: kc.; one thousand cycles. See CYCLE.

KILOVAR. Symbol: kVar. One thousand reactive volt-ampères. See VAR.

KILOVOLT. Symbol: kV. One thousand volts.

KILOVOLT-AMPERE. Symbol: kVA. One thousand volt-amperes. See VOLT-AMPERE.

KILOWATT. Symbol: kW. One thousand watts. See WATT.

KILOWATT-HOUR. Symbol: kWh. One thousand watt-hours. See WATT-HOUR.

KINEMATIC VISCOSITY. One of the factors that determine the resistance encountered by a body moving through a fluid (see REYNOLDS' NUMBER). The kinematic viscosity is the viscosity of a fluid (which term includes both liquids and gases) divided by its density.

KINETIC ENERGY. The energy which a body has by virtue of its motion. An example of rotary kinetic energy is found in the flywheel of an engine. The energy stored by the flywheel during the power stroke of the piston is expended during the non-power strokes to keep the crankshaft in motion.

KINETIC FRICTION. Friction in motion; the clutch of a motor vehicle provides an excellent example. Here two members are rotating by mutual friction as distinct from the action of the brake, where static friction is applied to the rotating brake drum.

KING CLOSER, see CLOSER.

KIRCHHOFF'S LAWS. Laws obeyed by electric currents when flowing in a network. They state that the sum of the currents, meeting at a common point, is zero and that the sum of the voltage drops is equal to the e.m.f. in any closed circuit.

In applying the first law a current flowing away from the point must be reckoned as being negative and in

applying the second it is necessary to take account of the directions of the current. This may not be the same in all parts, because the law is not restricted to single-circuit networks.

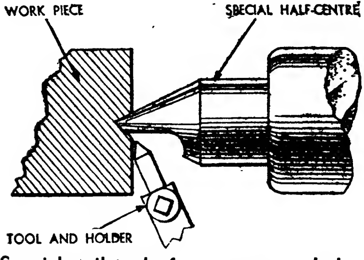
KLYDONOGRAPH. An electrical apparatus for recording surges on a photographic plate. Disk electrodes are placed on each side of the plate and, when it is developed, a circular figure appears. The diameter of this figure is taken as a measure of the greatest voltage experienced and its nature depends upon the polarity of the electrode touching the coated side of the plate. See SURGE.

KLYSTRON. A special type of radio valve suitable for operation at very high frequencies. Besides its use as an oscillator, it may also function as an amplifier or as a detector. It was invented by the brothers Russell and Sigurd Varian at Stamford University, U.S.A.

KNIFING TOOL. One of the most important of lathe tools. It has a sharp cutting-angle and can be used for straight turning after a roughing cut has been taken, or for facing the end of a workpiece held either in a chuck or between centres.

In the case of, say, round bars of small diameter held between centres, damage would sometimes be done to the tailstock centre if it were of the ordinary type, and a special form, as illustrated, has therefore been devised for use with knifing tools. In this special form, part of the tapering portion is removed to enable the tool to cut right up to the centre of the workpiece.

Though cuts may be made when



Special tailstock for use on a lathe in conjunction with a knifing tool.

moving the tool both towards and away from the centre of the work, the finishing cut should always be made from the centre hole outwards. If the volume of metal to be removed in facing is considerable, it may be quicker to take a number of roughing cuts, feeding the tool sideways, and to step off the metal to be removed in a series of side cuts rather than to keep to radial feed.

KNOTS. Breaks in the regular fibrous growth of timber; they appear as a series of concentric rings formed by a transverse cut across the fibrous growth of a branch. They are heavily charged with crude resin which exerts a solvent action upon superimposed films containing linseed or other drying oil, causing them to become discoloured and sticky. They are most pronounced in timbers obtained from coniferous trees. See KNOTTING and TIMBER.

KNOTTING. A material produced for creating an impenetrable film between knots and superimposed paint and varnish. Knottings consist of shellac dissolved in commercial alcohol, and are best applied as one coating with a thin solution to obtain penetration of, and grip upon, the surface, followed by one coating of greater substance to obtain insulation.

KNURLING. Roughening of a surface by mechanical means in order to provide a better grip, as on a micrometer nut, or as a substitute for keying small cylindrical items together. The method involves the production of regular, square pyramids on the surface by the intersection of right- and left-handed grooves, which in turn are produced by the knurl itself. The latter is a hardened tool held in the slide rest of a lathe and brought to bear against the workpiece, on which its burring action produces the knurled surface.

The knurling tool is usually in the form of a roller, free to rotate on a short axis and often arranged in duplicate so that similar knurls, one with right- and one with left-handed grooves, are held one above and one below the horizontal centre line of

the workpiece. In such cases the tool holder is provided with a horizontal hinge to allow some degree of vertical freedom (i.e. a floating movement) to the knurls. The angle of the helix adopted for the knurls determines the fineness or coarseness of the results.

In the actual operation, the knurls are forced into the workpiece by pressure obtained through feeding the slide rest inwards; the feed screw nut is then locked, to provide the necessary traversing motion. A copious supply of coolant or oil may be needed.

In numerous cases, however, the workpiece being comparatively short, no traversing motion in a longitudinal direction will be needed.

Serrations which are straight and parallel with the axis of the workpiece can also be produced if no traverse is used; this is the kind used as a substitute for keying small parts together, an external knurled surface being made to "mate" with a plain internal bore, into which it is pressed.

KODAK FLUORESCENCE PROCESS. A printing process designed to produce perfect colour rendering. Special paints are used to produce the original copy, and the range of eighteen water-colours is found to be ample for all practical purposes. These colours appear normal in ordinary light but are fluorescent to ultra-violet light.

Separation negatives are made for blue and yellow printer by arc lamps which are modified by specially fitted hoods containing compensating filters. This light causes fluorescence and thus provides extra density where colour correction is required. For red and black printer, unscreened light is used.

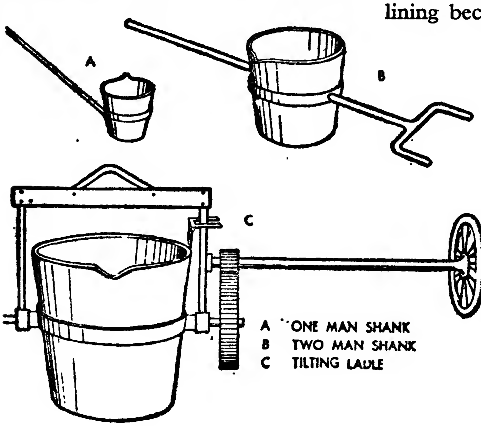
KOLOPRINT MACHINE. A Canadian development for printing directly on to bottles. Up to four colours can be printed simultaneously. Special inks are used and superimposition is possible without smearing. The bottles are fed and delivered from the machine automatically.

LABILE STATE, see METASTABLE STATE.

LABRADORITE, see FELSPARS.

LACTOSE, see CARBOHYDRATES.

LADLES AND SHANKS. Receptacles used to carry molten metal from the furnace to the moulds. The outer case is of mild-steel plate and is lined with ganister. Ladles are carried by cranes or on a trolley; shanks are carried by hand. Typical examples of each are shown in the illustration. After each day's use, the lining becomes worn; any remaining metal or slag must be chipped out, the lining repaired, and a coating of clay-wash given. Thorough drying before further use is essential. Shanks may be dried by inverting over a crucible furnace; ladles by placing a coke fire inside.



Shanks shown at A and B are carried by hand, whilst ladle at C is hoisted by crane or transported on a trolley.

LAG. The angular phase-difference between two electrical vectors, or the

alternating quantities to which the vectors correspond. See PHASE DIFFERENCE and VECTOR.

LAKES (Painting). A class of coloured pigments which possess little obscuring power; used mainly as thin washes suspended in both oil and water mediums. They require to be extended upon a white ground to obtain their full colour value. A lake may be defined as an organic colouring principle combined with a metallic base, thus forming a coloured body which is insoluble in water. Originally these dyes were derived exclusively from natural sources and had a somewhat restricted range. The advent of basic coal-tar dyes has considerably extended the palette.

LAMBERT. A unit of luminous brightness applied to a source or a reflecting surface. It corresponds to one lumen or 0·318 candle per square centimetre. See LUMEN.

LAMINAR FLOW. A condition of flow in the boundary layer in which there is no turbulence. Consider a surface, such as that of an aeroplane wing in contact with air which is in steady motion. The molecules or minute particles of air directly in contact with the surface will be at rest, the layer above will move slightly, the next layer will be moving a little faster, and so on, until at a short distance from the surface, a mere fraction of an inch in fact, the velocity of the main mass of air will have been reached.

If the flow is smooth, that is, if the layers slide over each other, like a pile of sheets of paper that is pushed at the top, the flow is said to be laminar, and the region of transition from no velocity at the surface to the velocity of the main mass of air is called the boundary layer.

The drag of a body moving through the air will be much less if the flow in the boundary layer is laminar than if it is turbulent, that is, full of eddies.

LAMINATED BOARD. A development of plywood (q.v.) consisting of two or more outer layers, or thick veneer, and a centre core composed of numerous strips of wood which are

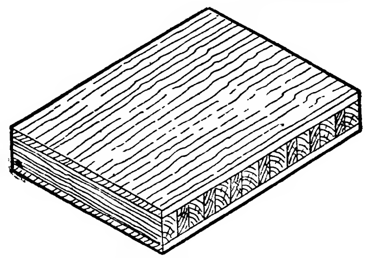


Diagram showing construction of laminated board. Centre core composed of strips of wood can be clearly seen.

glued together in the form of a thick, wide board as shown in the illustration It is also known as *laminwood*, *battenboard* or *blockboard*, according to the arrangement of the core. The construction of this type of board prevents shrinking and warping, and renders the board sufficiently stiff and strong to enable framing to be dispensed with, thus making it eminently suitable for use in the manufacture of flush doors, or for panelled framing, counter tops etc. Laminated board may vary in thickness from $\frac{3}{16}$ in. to over 2 in. and sizes up to 20 ft. × 8 ft. are obtainable.

LAMINATION (Elec. Engineering). A thin sheet of iron or steel, insulated

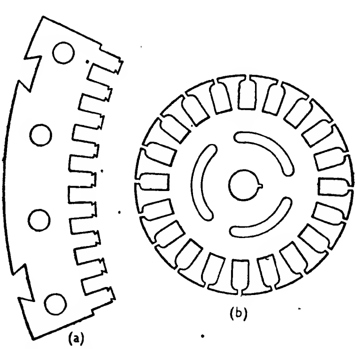


Fig. 1. Two types of lamination used in electrical work, showing part of a stator core (a) and rotor stamping suitable for a small machine (b).

on one side, used to construct some of the flux-carrying parts of electrical machinery. The object of lamination

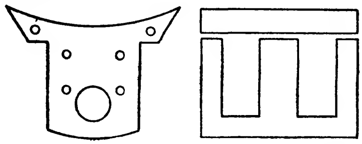


Fig. 2. Lamination built up to form a stator pole (left) and (right) pattern used for small transformers.

is to reduce iron losses. Some typical forms of lamination are shown in Figs. 1 and 2. Synonyms: Punching, Stamping. See IRON LOSS.

LAMINATION (Sheet-metal Work). A thin layer of non-metallic material present in steel. These non-metallic layers do not weld tight to the steel, and consequently, when the steel is worked, tend to be a point of weakness from which the steel cracks; parts of the steel may even break away.

One form of lamination occurs when the steel, during rolling or forging, is folded back on itself. Other origins are oxidized blowholes and the heavier non-metallic segregates associated with the top end of an ingot as cast. See INGOT.

LAMINWOOD, see LAMINATED BOARD and PLYWOOD.

LANTERN LIGHTS. Openings, usually in flat roofs, their purpose being to illuminate and ventilate rooms, staircases etc. They are constructed in a similar manner to lean-to or pitched roofs with hipped ends, and are often made of timber framing, with glass panels; but in modern practice metal framing is preferred.

The recent development of effective roof glazing has been assisted by the introduction of special glazing bars, which secure the glass, and provide a watertight joint without the use of putty.

In the construction of lantern lights, provision must be made for the trapping and discharge of condensation moisture, which will form on the inside surface of the glass. Reinforced glass should be used for glazing. See ROOF LIGHT and WINDOWS.

LANTHANUM (La). Atomic no. 57; atomic wt. 138·92. A metal belonging to the rare-earth class. It is a grey metal with a density of 6·16; m.p. about 816 deg. C. It forms alloys with aluminium and iron. It is trivalent and forms a chloride, $LaCl_3$, and other compounds.

LAP WINDING. A type of electrical armature-winding in which the ends of conductors are taken alternately forwards and backwards to meet the next conductor so that the coils overlap. In this winding there are as many parallel paths as there are poles in the machine.

These may not be electrically identical owing to variations in air gaps, so that equalizing connexions are needed to maintain at the same potential the points to which they are connected. See ARMATURE WINDING.

LASSOBAND. An adhesive plaster for mounting metal, plastic or rubber printing plates on wood or metal mounts. The advantage is that the plates may be cut flush.

LATENT HEAT. The amount of heat required to change a substance from solid to liquid state, or from liquid to gas, without raising or lowering temperature. The heat absorbed when 1 gram of a substance passes from the solid to the liquid state at its melting temperature is called the latent heat of *fusion*; that absorbed when 1 gram of liquid passes to the gaseous state at its boiling point is the latent heat of *vaporization*.

LATERAL DIHEDRAL, see DIHEDRAL ANGLE.

LATERAL STABILITY. A term used to denote the stability of an aeroplane about the yawing and rolling axes (see AXIS). Stability about the yawing axis is sometimes spoken of as directional, or weathercock, stability, because a directionally stable aeroplane is like a weathercock and will always tend to turn into the relative wind. It must be remembered that this "relative wind" always comes from ahead when the aeroplane is in steady, undisturbed flight, even if the machine is flying in a direction

at right-angles to that of the wind as felt by an observer on the ground.

Section (a) of the illustration shows a diagrammatic plan view of an aircraft which has experienced a disturbance causing it to be turned out of wind. The air meeting the fuselage at an angle will give rise to a sideways force on the fuselage as shown, and in nearly all cases this force will act at a point forward of the centre of gravity. Its effect will thus be to turn the machine still further out of wind; i.e., an aeroplane fuselage and wing with no tail is nearly always directionally unstable.

In order to counteract this tendency a vertical tail surface, or fin, is provided which also experiences a side force under the conditions described above. This force opposes the turning moment of the side force on the fuselage, and the problem of ensuring that a machine has an adequate degree of weathercock stability consists, therefore, of providing a vertical fin sufficiently large and sufficiently far behind the centre of gravity to overcome the unstable effect of the fuselage. For aeroplanes with more than one engine, the effect of engine nacelles (generally unstable) must also be considered.

The type of disturbance which necessitates the provision of stability about the rolling axis is shown at (b). The machine has been tilted over and is flying with one wing low. It will be apparent from a study of the forces shown that they are not in equilibrium, and that the machine will start slipping down in the direction of the lower wing. This motion is known as a sideslip. As soon as sideslip begins, the effect of dihedral angle (q.v.) makes itself felt. The manner in which this acts is shown in section (c) of the diagram. The sideways velocity due to sideslip (which is small compared with the forward speed) may be split up into two components, one parallel to the wing surface and one at right-angles to it. It can be seen that the latter component acts upwards on the lower wing and downwards on the upper

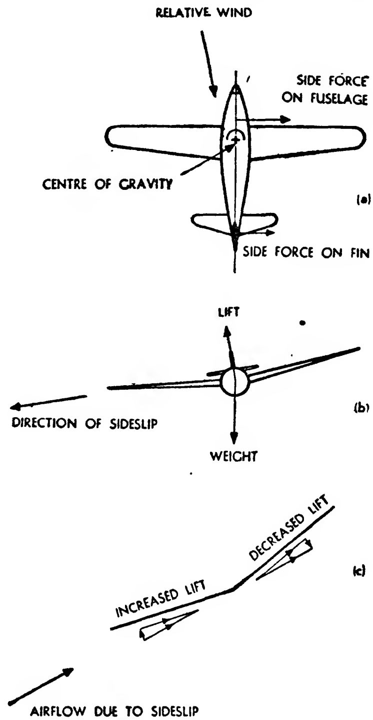


Diagram showing reaction of an aeroplane to disturbances of the kind often experienced in normal flight.

wing, the effect being to increase the angle of attack, and hence the lift, on the lower wing, and to decrease them on the upper wing. The lift differences form a righting moment tending to restore the machine to a level attitude.

For the sake of simplicity, the effects of fin surface and dihedral have been considered separately. In fact, both are called into play by the same disturbance, i.e. sideslip; it will be realized that the motion of the machine illustrated in the first diagram is in fact a sideslip with the wings in a horizontal plane.

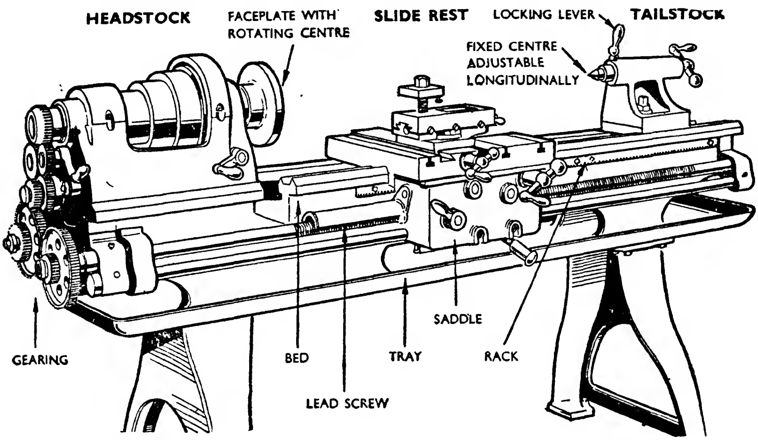
It is for this reason that the two forms of stability are known by the collective name of lateral stability, and that a designer has to consider the relative proportions of fin surface

and dihedral angle, as well as their absolute values.

LATH AND PLASTER. Except when plaster is applied to a solid surface, such as brickwork or concrete, some material must be provided which will form a rigid backing, or foundation, for the plasterwork. In forming this backing, preference is given to a material which provides open spaces or corrugations in its surface for the keying of the plaster. For many years the material in general use for this purpose consisted of strips of wood, termed "laths", these being nailed to the timber framing. The plasterwork obtained a grip, or key, by being pressed into the rough open joints between the laths.

During recent years, however, specially formed metal sheets with open mesh have been manufactured and used in preference to wood laths. Precast plaster slabs and pressed-fibre board sheets have very largely replaced the use of wood laths. See PLASTERWORK.

LATHE. A machine (see Fig. 1) for producing surfaces of circular cross-section on a workpiece which may be either rotated between horizontal centres or supported in a chuck, the tool performing this work being clamped on to an adjustable slide rest (Fig. 2). Lathes are used for producing cylindrical surfaces, tapered or conical work and work of irregular contour, provided always that the cross-section at any point is to be a circle. They are also used for facing the ends of work held in a chuck, for



CONE-DRIVEN LATHE

Fig. 1. Lathe of the type in general use in screw-cutting operations. This machine is equipped with sliding, surfacing and traversing mechanisms. The tailstock may be moved along the bed and clamped in any position to take varying lengths of work.

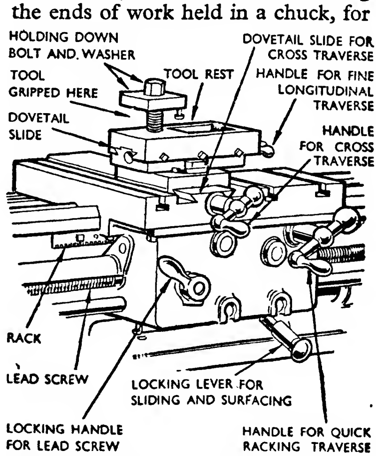


Fig. 2. Tools used in circular work are clamped in an adjustable slide rest.

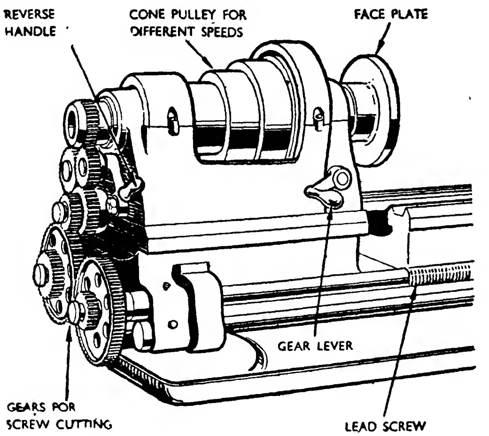


Fig. 3. Cone-driven headstock with external screw-cutting gears.

internal boring or drilling with the drill held in the movable centre or tailstock, and for thread cutting if equipped with the necessary gear. Knurling (q.v.) is also carried out on a lathe. Hollow castings and forgings which require to be turned are usually mounted on a mandrel which in turn is carried between the lathe centres.

Lathes have developed from the general-purpose engine lathe of a century or so ago along well-defined lines into specialized types, ranging from watchmakers' lathes to wheel lathes for locomotives, and the immense lathes used for machining large gun forgings. One of the most important types in mass-production work is the turret lathe, in which the slide rest carries a number of different tools which can be brought in turn to bear on the workpiece, thus enabling a whole sequence of operations to be carried out without resetting. Automatic lathes, in which the operations are determined by the contours and setting of a large rotating drum controlling all the movements, are another important division.

In early days, small lathes were driven by treadles; line-shafting and counter-shafting in workshops then came into favour but individual drive by electric motor is now frequently adopted.

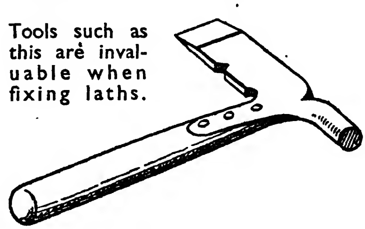
Another very valuable development is in the perfection of hydraulic control systems for feed and speed changes etc.

The *headstock* of a lathe comprises the casting housing the main spindle, together with the gear-changing devices giving the various available spindle speeds, and the gears which transmit the drive from the main spindle to the feed screw and—if the lathe is of the screw-cutting type—to the lead screw. At each end of the headstock are the main spindle bearings, which should be very accurately aligned with the axis of rotation of the spindle. The spindle itself is hollow, the bore being tapered at one end to accommodate the "live" centre.

There are two main classes of headstock: (a) the older type, illustrated in Fig. 3, with speed-cone pulley and external back-gear drive; and (b) the more modern type of geared head with single pulley to receive power from the lineshaft or individual motor. In the latter type a friction clutch and brake are used to control the power transmitted, while various combinations of the positions of two or three change-speed levers on the headstock enable a wide range of spindle speeds to be obtained. See CAPSTAN LATHE.

LATH HAMMER. A hammer with a cutting-edge or hatchet moulded integrally with the hammer-head as

Tools such as this are invaluable when fixing laths.



shown in the accompanying illustration. It is used for the dual purpose of nailing-on the laths and cutting

them to length, thereby saving the use of both hammer and hatchet separately. A slot is provided in the blade for extracting nails.

LAUAN. A Philippine wood with several species, marketed as red or white lauan, and used as a substitute for mahogany (q.v.). Lauan has the appearance of a soft mahogany, but is less stable.

LAY. A term used in connexion with stranded electric cables. It may mean the distance along the cable within which a strand makes one complete twist, but the word is sometimes used to indicate the ratio of that distance to twice the mean distance between the strand and the centre of the cable.

LAYLIGHTS. Glazed panels for indirect lighting. They are commonly associated with lantern lights, and form part of a suspended ceiling. When laylights are placed in this position the occupants of the room can enjoy artificial sunlight through the medium of an artificial lighting system fixed above the laylight. Provision must be made for access to the lighting fitment.

Laylights are constructed in the form of glazed horizontal panels, the framing being of wood or metal and the bars rebated to form a seating for the glass sheets. By the use of glass sheets of varying colours pleasing lighting effects can be produced.

LEAD. The angular phase-difference between two electrical vectors. If two vectors differ in phase, the one which first reaches, say, its maximum, is said to lead the other. Alternatively the second may be said to lag behind the first (see LAG).

The term is also used in connexion with brush gear of electrical machines to indicate a displacement of the brushes in the direction of commutator rotation from their no-load position. The amount of lead is usually measured either as an angle or in terms of commutator segments. See ARMATURE REACTION.

LEAD (Pb). Atomic no. 82; atomic wt. 207·21. A whitish or bluish-grey metal with a bright lustre when freshly cut. It is very soft and moderately malleable and easily rolled into sheets or extruded into pipes. It has a specific gravity of about 11·35, melts at about 326 deg. C. and boils at about 1550 deg. C. It is used in making bullets, accumulator plates, white lead, red lead and various lead alloys.

Lead is commonly smelted from ores containing galena, lead sulphide, PbS. The ores are mixed with fuel and roasted in a blast furnace. The pig lead so produced may contain silver, which is usually recovered by the Parkes process; the lead is melted with about 1 per cent of zinc, which rises to the top with the silver dissolved in it; this is skimmed off and the silver easily recovered.

Printers' type-metal contains about 72 per cent of lead, 18 per cent of antimony and 10 per cent of tin. The presence of about 0·1 per cent of tellurium makes lead tougher. The compounds of lead are of industrial importance; lead is tetravalent and forms a suboxide, Pb_2O, the monoxide litharge or massicot, PbO, the dioxide or peroxide, PbO_2, and red lead, approximately Pb_3O_4. The monoxide is made by roasting molten lead in contact with air; the oxide rises to the top; if it is solid it is skimmed off and called massicot; if the oxide melts it is run off and allowed to cool, when it forms the crystalline litharge. Red lead is an important pigment obtained by roasting white lead or massicot; orange lead is a finely coloured variety of red lead. Red lead has no definite composition and is probably an interstitial compound.

White lead is a basic carbonate of lead having a variable composition, corresponding roughly to the formula $2PbCO_3.Pb(OH)_2$. It is an important pigment, usually made by exposing strips or sheets of lead to air, carbon dioxide, steam and the vapour of acetic acid. The lead chromates, $PbCrO_4$ and Pb_2CrO_5, are valuable pigments. Lead nitrate, $Pb(NO_3)_2$, is used in calico printing and dyeing. Lead silicate is made by fusing litharge with silica so that it is insoluble in dilute acids and may be

used as a glaze for pottery. Lead tetraethyl, $Pb(CH_2CH_3)_4$, is a poisonous liquid, largely used with ethylene dibromide as an anti-knock mixture for internal-combustion engines.

LEAD-ACID ACCUMULATOR. An electrical secondary cell (q.v.). It consists of positive and negative plates immersed in dilute sulphuric acid. Pasted plates consist of a grid or lattice made of lead with a paste of lead oxide pressed into the interstices. After pasting, the plates are converted by electrolysis into positives and negatives. The paste in the former becomes lead peroxide, while in the latter it is reduced to a spongy form of lead. Positive plates may also be prepared by forming, which is an electrolytic process. The starting point in this case is a plain lead plate.

When the plates are immersed in the electrolyte a cell is produced. During discharge the lead peroxide is converted to lead sulphate and the spongy lead in the negative combines with the acid to form the same substance.

An additional product of the chemical change is water, so that the specific gravity of the acid falls as the discharging progresses. The cell may be recharged by passing a current through it in the opposite direction. The chemical changes then reverse, the specific gravity rises, and the original conditions are restored.

The e.m.f. of a fully charged cell is about 2·3 volts. During discharge the voltage falls almost at once to about 2·1 volts and then more slowly, remaining around 2 volts for the useful period of discharge and then falling rapidly as the cell becomes exhausted at about 1·8 volts. During this period the specific gravity falls from about 1·2 to about 1·15, and this property gives a useful indication of the state of charge and discharge.

The capacity of a cell is computed in ampere-hours (q.v.) but capacity depends upon the rate of discharge, i.e. the current taken. Thus a cell with a capacity of 60 Ah at the 10-hour rate might give only 30Ah at the one-hour rate. See ELECTROLYTE and GASSING.

LEAD BATH. A bath, or pot, of molten lead used in heat treatment for heating steel articles prior to quenching. Its use is confined to the heating of such steels as will harden effectively from below about 950 deg. C. A simple form of lead pot consists of a graphite crucible (10-lb. size) enclosed in a refractory casing and heated by means of an injector-type gas burner.

Oxidation and consequent slagging of the lead are prevented, either by restricting the flow of air to the burner, the large reducing flame so produced covering the surface of the lead and preventing access of air, or by covering the surface of the lead with charcoal granules. Whichever method is adopted, it is very difficult to judge the temperature of the lead by the appearance of its surface. For this reason lead pots are generally fitted with pyrometers.

In practice, the lead pot is used largely in the heat treatment of such parts as chisels, rivet snaps, gauges etc., which require hardening locally. Thus in hardening a chisel about half-an-inch to one inch of the tip is immersed in the lead. After a short time, when the tip has reached the same temperature as the lead, the chisel is withdrawn and quenched in the usual way. For this class of work the lead pot is most convenient and rapid. Where general hardness is required a salt bath (q.v.) is more suitable.

LEAD CHROMATE, see CHROMIUM.

LEADED BRONZES. Phosphor bronzes to which additions of lead up to 15 per cent have been made. Lead is not soluble in bronze in the solid state, but is merely contained in it in the form of rounded globules. These do much to increase the plasticity of the metal and so improve its properties as a bearing material, without destroying the hardness conferred by the phosphorus. Such alloys are much used for small-end bushes of internal-combustion engine

connecting rods, and give excellent service when run in conjunction with hardened steel.

LEAKAGE FACTOR. The ratio of the total magnetic flux produced in an electrical device to the amount of flux usefully employed. For example, some of the flux produced in the poles of a generator finds its way to an adjacent pole without traversing the armature. This factor is necessarily greater than one. See MAGNETIC LEAKAGE.

LEAKY-GRID DEMODULATION. A system of demodulation depending for its action on the fact that, if the grid of a valve is made positive, grid current will flow. (The grid and cathode of such a valve act almost exactly like the anode and cathode of a diode). The rectified, i.e. demodulated, signal appearing at the grid is then amplified in the usual way by the valve as a whole.

LECLANCHÉ CELL. A primary electric cell consisting of a zinc cathode and a porous pot immersed in a solution of sal-ammoniac. The porous pot contains the anode surrounded by a mixture of manganese dioxide and carbon, which acts as a depolarizer.

LEDGED DOORS, see DOORS.

LEFT-HAND THREAD. A screw-thread cut in the opposite direction to the normal and used when a customary right-hand thread would tend to unscrew. Alternatively, the workpiece may have two threads—a left-hand and a right-hand—cut on it, one at each end, as is the case with certain turnbuckles and screw-coupling components.

Any lathe which can be used for cutting right-hand threads will equally well cut left-hand threads. For the latter, however, it is necessary to reverse the direction in which the lead screw revolves. A forward (i.e. anti-clockwise) rotation of the lathe spindle will thus compel the carriage to travel towards the tailstock instead of towards the faceplate. The cut is started at the end of the thread next to the facepiece, and is continued towards the tailstock. It is a good plan to turn a groove beforehand in which the cutting tool can engage at the beginning of its travel.

LEG, see LIMB.

LEITCH'S PROCESS. A method of producing a relief printing block by transferring a suitable transfer or re-transfer to zinc by the lithographic method, establishing the image and etching to the required depth. The method preceded those using light-sensitive bases.

LENS. A glass or other transparent substance bounded by two spherical surfaces or by a spherical surface and a plane surface. The various kinds of lens are: biconvex (two convex surfaces), plano-convex (one surface plane and the other convex, convex meniscus (one surface convex, and the other concave, with a greater radius of curvature), bi-concave, plano-concave, concave meniscus (the convex surface has the greater radius of curvature). The position of the image formed by a lens may be found from the formula: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, where u is the distance of the object from the centre of the lens, v is the distance of the image, and f is the focal length of the lens. Distances to the right of the lens are $+$, distances to the left are $-$. Magnification by a lens $= \frac{v}{u}$.

LENZ'S LAW. A law of electro-magnetic induction which states that induced currents have such a direction that they try to oppose the change producing them.

LETTERPRESS PRINTING. The oldest and most widely used of modern printing processes. It comprises almost the whole of the relief group, and is more utilitarian than the rest of the graphic processes. Letterpress printing consists of inking a raised, or relief, surface and transferring the ink to paper by pressure.

Printing surfaces include single metal type characters assembled either by hand or mechanically; lines of metal type, called slugs; duplicated blocks or stereotypes cast from type metal in line or half-tone; blocks of copper known as electrotypes and

produced by electro-deposition; blocks of moulded plastic or rubber; photo-engravings; wood types for posters, woodcuts and wood-engravings. These are used separately or in combination as required. Examples of the very wide range of machines used are hand platen, automatic platen, flatbed single and two-colour, perfecting, rotary sheet-fed single colour and perfecting.

The larger newspaper web machines are built on a unit system which allows practically any desired output. These are also built to print in full colour. Finally, the multi-colour rotary, printing four colours on each side of the web as it passes once through the machine, has been brought to a high stage of development in America. The work produced by this method is equally wide, ranging from visiting cards, handbills, office stationery and general commercial work to high-grade colour work, books, periodicals and newspapers.

LEVER. A rigid rod which turns about a point called the *fulcrum* (q.v.). A bent lever is called a *crank*. Levers

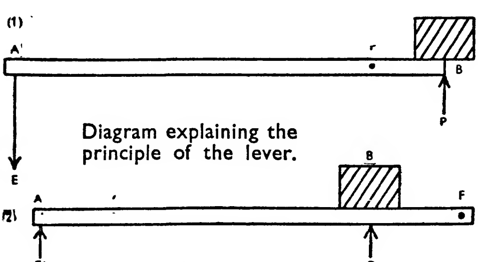


Diagram explaining the principle of the lever.

are used for moving heavy weights by the use of a comparatively small force. In lever (1) in the accompanying diagram the fulcrum is at F; a downward pressure (E) at A is used to exert an upward pressure (P) at B. Then E × AF = P × BF. In lever (2) the fulcrum is at the end of the lever (F). An upward pressure (E) at A is used to exert an upward pressure (P) at B. Then E × AF = P × BF. Many tools involve the lever principle. Scissors, pliers, pincers, shears, nutcrackers are examples of double levers.

LEYDEN JAR. An early form of electrical condenser consisting of a glass jar with conductors, usually of metal foil, covering the greater part of the outside and inside surfaces. See CONDENSER.

L.F. (Radio). Low frequency (q.v.).

LIFT (Aero. Engineering). The force that sustains an aeroplane in the air. It is derived from the dynamic reaction of the air upon the wing, the induced drag being a part of the price that has to be paid to obtain this reaction.

LIFT COEFFICIENT. An expression of the lift of an aircraft wing in relation to its size, the angle of attack, speed at which the aeroplane is flying and the atmospheric density. If

L = lift in lb.

S = wing area in sq. ft.

ρ = air density in slugs/cu. ft.

V = speed of the aircraft in ft./sec.

then

$$L = C_L S \rho \frac{V^2}{2}$$

The lift coefficient varies linearly with the angle of attack nearly up to the stall. A few degrees before the stall, the rate of increase of lift coefficient with incidence begins to fall off, until, just before the stall, its maximum value is reached, after which its value falls off very rapidly. See COEFFICIENT.

LIFTERS, see GAGGERS.

LIFTING STAPLES. Pieces of iron- or steel-bar shaped like a letter "U". They are cast into core irons to enable lifting tackle to be attached and the core lifted without damage. The ends of the staple should be nicked or bent to prevent pulling out. The number and size of staples required depend on the size and shape of the core. Three ½-in. staples will lift a ton safely; and three 1-in., 7 tons. They should be so placed that the weight of the core is well distributed with a minimum of spring. Four staples may sometimes be used, but great care must be taken

in adjusting the chains or the load may be supported largely by two staples and an undue strain put on the core.

LIGHT ALLOY. A non-ferrous alloy having aluminium or magnesium as a base, the upper limit to the density being approximately 3. The pure metal is alloyed with metallic or non-metallic constituents in amounts up to about 12 per cent, such alloys having a wide range of properties.

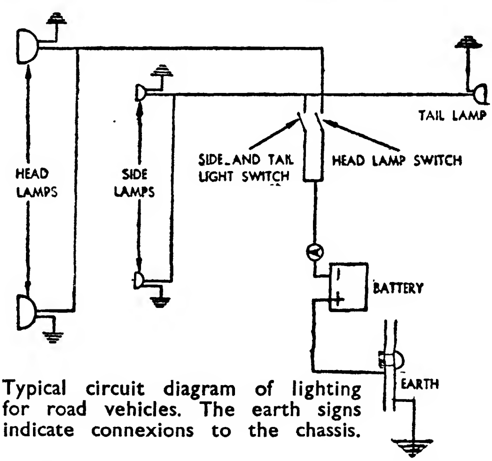
Aluminium is alloyed with copper, manganese, magnesium, silicon, iron, titanium, nickel etc., giving alloys whose tensile strength may exceed 30 tons per sq. in. Alloys containing copper have a high strength combined with a low weight and are suitable for structural purposes. Many alloys of this type attain their maximum properties on heat-treating and age-hardening. Aluminium alloys containing magnesium have higher corrosion resistance than those containing copper, but generally have lower strength values. Aluminium-manganese alloys combine moderate strength with good resistance to corrosion. Aluminium alloys are made in both the cast and wrought forms.

Magnesium alloys are used where exceptional lightness combined with strength is required, in aeroplane construction for landing wheels, undercarriages, airscrews, tail-wheel yokes etc. The alloying elements present in magnesium are chiefly aluminium, zinc and manganese.

The unique properties of the light alloys make them particularly suitable for conditions under which high strength combined with lightness is required.

LIGHTING FOR MOTOR VEHICLES. This normally consists of head, side and rear, or tail, lights. British laws require that every motor vehicle with three or more wheels must carry two side lamps showing its full width and a rear lamp which illuminates the rear number plate and shows a red light to following traffic.

Headlamps are necessary to illuminate the road ahead for safe driving. The side and headlamps, similar in shape though not in size, consist of an outer shell, reflector, holder to support the bulb, and lamp front and glass. A little attention is all that is required to maintain the lighting system in good condition, but cleanliness is of first importance. Periodically wash the outer surfaces of the lamp glasses and bulbs and polish the reflectors with a soft cloth or chamois leather. Metal polishes should not be used as the reflector is usually protected by a transparent covering. Lamps and lamp brackets must be held securely or the life of the bulb will be considerably reduced by vibration. The appropriate circuit is shown in the above diagram.



Typical circuit diagram of lighting for road vehicles. The earth signs indicate connexions to the chassis.

Headlamps. The efficiency of headlamps is impaired if they are not properly focused. Lampholders are provided with means of adjusting the position of the bulb in relation to the reflector. The correct position is determined by focusing the light of the lamp on a flat surface and moving the lamp in or out of the reflector until a full beam of light, free from patches, is obtained. After focusing,

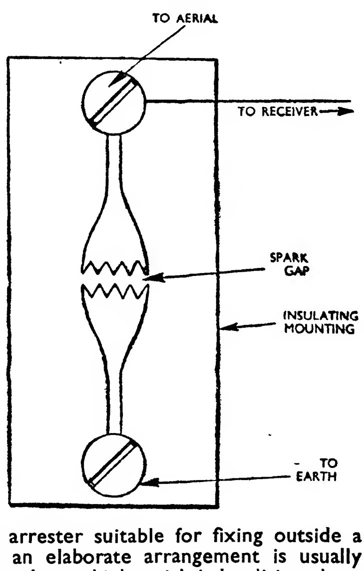
the headlamps should be so set that at a distance of approximately 25 ft. the centres of the beams of both headlamps are the same height from the ground as the centres of the lamps. They should also be set the same distance apart.

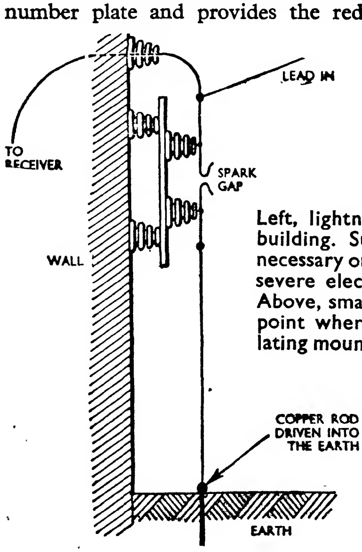
Dipping Headlamps. These are of two general types, dipping reflectors and double filament bulbs. In the first method the near-side reflector is provided with a solenoid-operated mechanism that dips the whole reflector downwards and sideways. A switch for the offside lamp is also incorporated so that when the reflector is dipped the offside headlamp is switched off. The second means of dipping is effected by using a special type of bulb with a filament at its focal centre and another one slightly off-set. Normally the light is reflected straight ahead, but when dipped the out-of-centre filament throws the light on to the top half of the reflector which, in turn, throws it on the ground a short distance in front of the vehicle.

Tail Lamp. The modern type of tail lamp is divided into two compartments with a lampholder and bulb in each and a clear glass in the side of the shell and a red one in the end. One bulb illuminates the rear number plate and provides the red light, the other bulb being switched on automatically as a warning when the foot brake is applied. Some tail-lamp bulbs contain two filaments, however, one for the brake light and one for normal lighting.

Bulbs. These are manufactured for use on earth-return or insulated-return systems and are known respectively as S.C.C. and S.B.C. They are of varying power, rated in watts; those of side and tail lamps 3 or 6 watts, those of headlamps 24 or 36 watts.

LIGHTNING ARRESTER. A device connected between aerial and earth for the purpose of protecting radio gear in electric or thunder storms. Ordinarily, it is non-conducting, but in the event of a large e.m.f. being induced into the aerial by a nearby flash of lightning, it will flash over and conduct. The current will accordingly pass direct to earth instead of finding its way through the apparatus it is desired to protect.





Left, lightning arrester suitable for fixing outside a building. Such an elaborate arrangement is usually necessary only with very high aerials in localities where severe electrical storms are frequently experienced. Above, smaller type of arrester generally fitted at the point where the lead-in enters a building. The insulating mounting is usually made of ebonite or porcelain.

Two typical flash-over or spark-gap kinds of arrester are illustrated. Other types of arrester include the gas-filled (usually neon) two-electrode tube which will conduct heavily when the voltage across it exceeds a certain value.

LIGHTNING CONDUCTOR. An electric conductor running to earth as directly as possible from a point above a building.

LIGNITES, see FUELS.

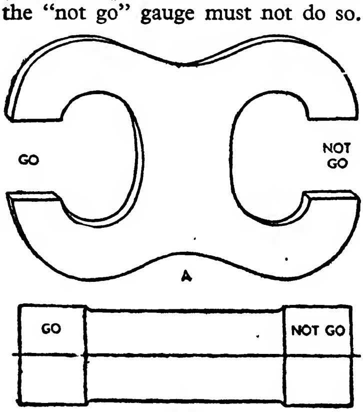
LIMB (Elec. Engineering). The part of the magnetic circuit of a transformer around which the coils are placed. Synonym: Leg. See MAGNETIC CIRCUIT.

LIME, see QUICKLIME.

LIME GREEN, see GREENS.

LIMEWASHING, see DISTEMPER.

LIMIT GAUGE. A device enabling an operator to make sure that the dimensions of a workpiece will lie between two definite measurements known as the high and low limit respectively. The forms which such gauges take depend upon the workpiece. One common form, known as a double-ended snap gauge, which is a convenient type for use on male pieces, is shown at (a) whilst that at (b) is a double-ended plug gauge for checking internal bores. In all such gauges the principle is that the workpiece can be accepted if the "go" gauge will pass over or into it; while the "not go" gauge must not do so.



Two types of gauge used as standards to check dimensions of a workpiece.

The difference in perpendicular distance (A) between the jaws of the "go" gauge and those of the "not go" gauge, or the difference in diameter (B) of the two ends of the plug gauge—too small to be shown in the drawing—is known as the *tolerance* (q.v.).

LIMIT OF PROPORTIONALITY, see LOAD-EXTENSION DIAGRAM.

LINCRUSTA, see EMBOSSED WALL COVERINGS.

LINEAR DEMODULATOR. In radio receivers, a demodulator in which the relation between carrier voltage and the corresponding change in anode current obeys a linear law; i.e. one is directly proportional to the other. Diodes belong to this class.

LINE CORD. A ballast resistance for use with certain types (chiefly small A.C.-D.C. models) of radio receiver; it takes the form of a resistance wire wound around, and suitably insulated from, the power-supply lead. A resistance of this type provides a convenient method of dissipating the heat generated in it. See BALLAST RESISTANCE.

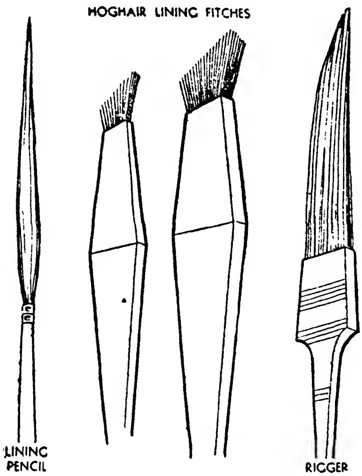
LINE OF MAGNETIC FORCE. An imaginary line traced in a magnetic field such that its direction at every point is the direction of the magnetic force at that point. The density of the lines of force is often taken as a measure of magnetic force, and the number of lines per square centimetre as representing the magnetic force exerted in that area. Abbreviations: Line of force, Line. See MAGNETIC FLUX DENSITY and MAXWELL.

LINER (Auto. Engineering). A hollow steel or cast-iron open-ended cylinder, or sleeve, used to reduce the original size of a cylindrical hole. In internal-combustion engines, the wearing surfaces of cylinder bores are frequently fitted with liners so that they can be renewed when excessively worn.

LINER (Painting), see LINING.

LINE TURN, see LINKAGE.

LINING (Painting). The operation of running a line of colour, either to



Brushes, known as fitches, used by painters in the lining process.

give clear definition between two colours which appear to merge or as a simple type of decoration. The colour is applied with brushes as shown—lining pencils, sometimes known as liners or riggers, and lining fitches—varying in size to give lines from a hair's breadth to an inch in thickness, and made specially for this purpose.

LININGS (Building). Wood or plaster coverings which are used to conceal the structural part of a building. The term is usually prefixed by the name of the portion of the structure which it is intended to cover, such as *wall linings*, *jamb linings*, *window linings* and *soffit linings*. Wood linings are usually fixed to timber grounds and backings, and, if more than 12 in. wide, they are usually framed and panelled.

LINING-UP. When two shafts of a mechanism are placed end to end, and a line through the centre of one coincides with a line through the centre of the other, the two shafts are said to be lined up, or in alignment. When shafts are connected rigidly they must be in perfect alignment or excessive wear, possibly a complete breakdown, will result. On automobiles, for instance, such components as magnetos, dynamos, starter motors, pumps etc., must be correctly lined-up. See STEERING.

LINKAGE (Elec. Engineering). A line of magnetic force threading one turn of a conductor. One hundred million linkages produced by one ampere provide an inductance of one henry. Synonyms: Interlinkage, Line turn. See INDUCTANCE.

LINOXYN, see LINSEED OIL.

LINSEED OIL (Painting). The standard oil used in mixing oil paint. It is obtained from the seeds of the flax plant. Linseed oil belongs to a class of oils termed "unsaturated".

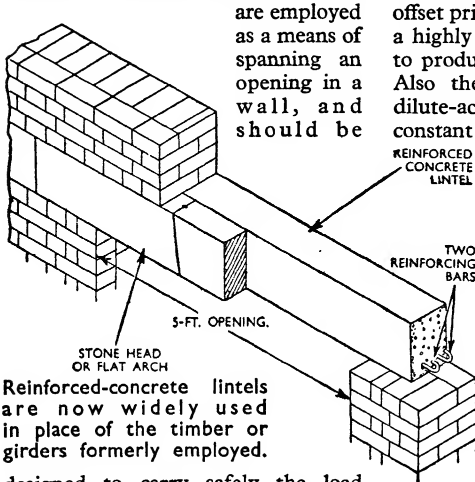
Such oils, when extended as a film, abstract and assimilate oxygen from the atmosphere and change from a liquid into a tough, leathery substance (in this case *linoxyn*) which attaches to any clean surface upon which the transformation has taken place. In liquid form linseed oil is readily soluble in turpentine and white spirit, but the dry film withstands their action and is also fairly waterproof.

The oil is supplied to painters in two forms: *Refined* and *boiled*. The first is a clear, pale, amber-coloured liquid which, after abstraction, has been treated with weak acid to remove all unwanted mucilaginous, or gummy, matter and given time for solids to settle out; this oil, when extended as a film upon clean ground glass and exposed to normal daylight in a temperature of from 60 to 70 deg. F., should be surface-dry in four days. *Boiled* oil (q.v..) is the raw oil which has been subjected to prolonged heating, during which salts of various metals, termed driers (q.v.), are added to speed up its drying time. It is a clear liquid varying in colour from a deep amber to a rich brown; when extended as a film upon a clean ground glass and exposed to normal daylight in a temperature of from 60 to 70 deg. F. it should be surface-dry in twenty-four hours.

Boiled oil dries with greater gloss than untreated oil, and is used extensively for external painting. *Stand* oil and *blown* oil are both

partially oxidized forms of linseed oil which are used by paint manufacturers in the fabrication of enamels and gloss paints; they are not stocked or used by painters for mixing ordinary oil paint.

LINTEL. A horizontal structural member, placed over an aperture to discharge the superincumbent weight. Lintels, sometimes known as lintols, are employed as a means of spanning an opening in a wall, and should be designed to carry safely the load placed upon them as shown above.



Reinforced-concrete lintels are now widely used in place of the timber or girders formerly employed.

Reinforced-concrete lintels are in common use in modern building construction. They are usually precast, and contain sufficient steel reinforcement to enable them to take the tensional stresses. As the maximum tensional stresses occur at the lowest part of a beam, the steel reinforcement should be placed as near as possible to the bottom of the lintel. The ends of the reinforcement should be hooked to resist any slipping tendency.

LIQUID DRIERS, see DRIERS (Painting).

LIQUIDUS. In metallurgy a line in an equilibrium diagram (q.v.), indicating the temperature at which any particular alloy is completely liquid. See SOLIDUS.

LITHIUM (Li). Atomic no. 3; atomic wt. 6·94. A light, whitish metal, density 0·54; m.p. 189 deg. C.; b.p. 1336 deg. C. Chemically it resembles sodium and potassium. It is monovalent and forms a dihydride, LiH, a hydroxide, LiOH, an oxide, Li_2O, and a peroxide, Li_2O_2.

LITHOGRAPHIC OFFSET INKS. These printing inks are very similar to letterpress inks, but are heavier-bodied because of the higher proportion of pigment to medium. As the ink film which is carried to the paper by offset printing (q.v.) is extremely thin, a highly concentrated ink is required to produce intensive colour strength. Also the ink must be water- and dilute-acid-resisting or, owing to its constant contact with the moistened printing surface, it will bleed and stain the paper. Free transference is required from rubber blanket to paper, and heavy inks tend to cake, clog or pile.

LITHOGRAPHIC VARNISH. Linseed oil of highest quality which has been thickened by heat. Made in several standard consistencies by varying the time of heat application. Grades are known as tint, thin, middle strong and extra strong; in this order the grades increase in viscosity, the tint being slightly thicker than the pure oil, while the extra strong is elastic-like. To produce the tint grade, the temperature is maintained at about 550 deg. F. for approximately one hour, while 24 hours may be required to produce the extra strong grade. Intermediate viscosities may be calculated on a time basis or tested by cooling samples at intervals.

LITHOGRAPHY. The chief process in the planographic printing group; it is probably unique that its invention and early progress were due to the efforts of one man, Aloysius Senefelder. After many experiments in relief and recess printing, lithography emerged in 1798 as a planographic printing method.

The surface used by Senefelder was an extremely fine-grained calcium carbonate, and although stones are

still used this method has been superseded by the use of zinc and aluminium plates. The required image is drawn on the dry surface with suitable tools and a water-miscible ink containing fatty acids and soap. When dry, the surface is moistened with water and a roller, charged with a waterproof printing ink, is rolled over it; the practical effect of this is that the printing ink adheres selectively to the drawn sections.

As the dry stone or plate still retains an attraction for ink, restraining or controlling means must be taken to prevent this; and a solution of gum arabic (q.v.) is distributed over the whole of the surface. This gum does not affect the stone where the image is already established, but is absorbed and adsorbed by the rest of the surface. The surplus gum subsequently washes away with water, but a combined film remains in the surface and has water-attracting, and therefore ink-resisting, qualities.

Before printing begins the stone or plate is usually etched with a dilute solution (say 2 per cent) of nitric acid, followed by a further application of gum. This etching operation is designed primarily to improve the water-retaining qualities of the non-image section.

A great advantage of the lithographic process is the facility with which duplicate printing surfaces can be made, once an original printing image is obtained. Assume this drawing to be a label of which a large number is required. Impressions would be taken on a special transfer paper with special retransfer ink and mounted to predetermined position on a base sheet of suitable size. These retransfers are pressed on to another prepared printing surface, which is then established and sent to the machine, while the original image may be retained for future use.

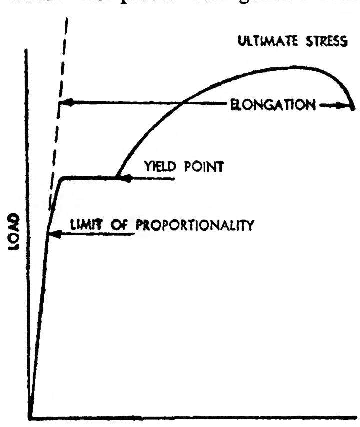
Stone slabs, which are cumbersome, are limited to the flatbed type of machine, and have been largely replaced in modern practice by flexible zinc and aluminium sheets or plates, which readily clamp round a cylinder and allow the use of smooth rotary motion and high speeds. Other surfaces, both metal and non-metal (including plastics), have a less general but increasing use.

Lithographic productions, which range widely in diversity and quality, include facsimile letters etc., labels in one or more colours, business stationery, illustrated sheets and catalogues, posters, show-cards, calendars, reproductions of works of art, metal-box and tablet decoration, newspapers, periodicals and bookwork. See AUTOLITHOGRAPHY.

LITHOPONE (Painting). An opaque white pigment formed by the combination of zinc (q.v.) and barium (q.v.) compounds; used mainly in the making of washable distempers, water paints and the less expensive flat gloss oil paints for internal use only.

LIVERING, see CURDLING OF PAINT.

LOAD-EXTENSION DIAGRAM. A diagram obtained by plotting load against the extension produced on a tensile test-piece. The general form



Load-extension diagram for mild steel.

of the curve obtained with mild steel is shown in the above graph. At first the extension produced is proportional to the load applied, until the Limit of Proportionality is reached.

Further increase in load produces a slight deviation from the straight line until suddenly a large extension is

produced without further increase in load. The load in tons per sq. in. at which this occurs is known as the yield point (q.v.) and is a value often required by specifications. From this point onwards the material behaves in a partly plastic, partly elastic, manner, as indicated by the curve, until the Ultimate Stress of the material is reached.

A decrease in load may then be observed due to a considerable local reduction in the cross-section of the test-piece. Other ductile materials show curves of similar shape except that no yield point is generally given.

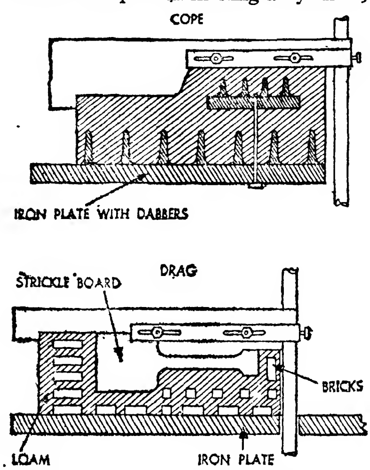
LOAD FACTOR (Aero. Engineering). A factor used in the design of aircraft in place of the Factor of Safety used in General Engineering. In order that an aeroplane shall be strong enough to withstand the loads imposed upon it in various conditions of flight, it is customary to design its structure so that it is capable of withstanding a certain number of times the load it has to carry when the aeroplane is in steady flight.

The number by which this load is multiplied is called the load factor. It is usually assumed that if the aeroplane is expected to have, say, five times the load in steady flight imposed on it due to manoeuvring, air gusts etc., then the load factor shall be twice this figure, to allow for a reasonable margin of strength, thus, although the load factor is 10, the real factor of safety is only 2.

LOAD FACTOR (Elec. Engineering). The ratio of the total number of units of electricity supplied by a generating station in, say, a day, to the number which would be supplied if the load remained at its maximum value throughout the day. This factor cannot exceed unity, or 100 per cent. An average value is 40 per cent.

LOADING. Mineral substances used in papermaking, which are added to the pulp when in the beating engine to fill-in the spaces between the cellulose fibres. Suitable loading improves the feel, weight, opacity, printing quality, ink absorption and smoothness of the paper surface. The chief materials used for loading are china clay, or kaolin, barium sulphate, titanium oxide, agalite and talc.

LOAM MOULDING. A method of moulding used mainly for large circular moulds, for which it is often most economical, since no pattern or moulding box is generally required. The method is best illustrated by an actual example. In making a flywheel,



In the loam-moulding process, the mould, when complete, is oven dried and its surfaces covered with blacking in the same way as dry-sand moulds.

a layer of loam is first laid on a heavy cast-iron plate; then a layer of bricks, the spaces between the bricks being filled with cinders and loam.

Successive layers of loam and bricks are added to build-up the rough shape of the lower half of the mould. Plastic loam is smoothed on with the hands and swept into shape by a rotating strickle board (q.v.) supported on a centre spindle. The strickle board has one square edge and one bevelled. In roughing, the square edge should always lead. More loam is added when required and the strickle again rotated, until a reasonably accurate mould is obtained. A thin coating of very moist loam is smoothed on and the strickle rotated once only with the bevelled edge leading, to leave a perfectly smooth surface.

The top half of the mould is made

similarly, using iron plates with dabbers projecting into the sand, as shown in the illustration, instead of bricks. These plates have a number of holes in them to permit adequate venting. Some of the holes are, of course, used for pouring the casting, and for the risers. Loam moulding is not confined entirely to the manufacture of circular castings. It may also be used for nearly circular work, any projecting parts being made by using patterns and core boxes.

LOCAL OSCILLATOR. A valve circuit used as a source of oscillations for frequency-changing on the heterodyne principle. See BEAT FREQUENCY.

LOFTING. The laying out or drawing of the lines of a fuselage, hull, or float etc., full size, on some suitable flat surface, in a similar manner to that in which a ship's lines are laid out in a mould loft. It is thus possible to obtain fair curves, check dimensions and make templates for bulkheads etc.

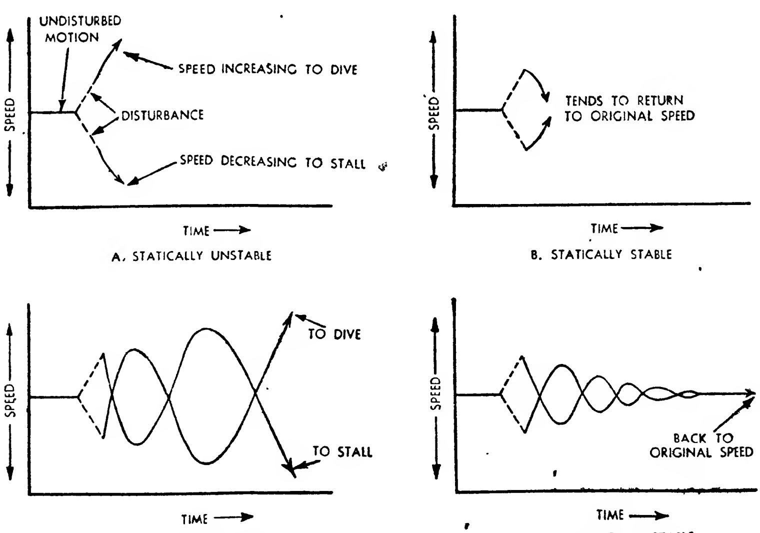
It is now sometimes the practice to photograph the lines once they have been drawn out, so that they can be transferred direct to the material of which bulkheads etc., will be made.

LOGARITHMIC DECREMENT. When the amplitude of a damped oscillation decreases in geometrical progression, the Napierian logarithm of the ratio of the maximum displacement of any oscillation to the maximum displacement in the same direction of the oscillation immediately succeeding it, is called the logarithmic decrement.

LONGERONS. The main longitudinal load-carrying members of fuselages, that is, of course, excepting those of monocoque (q.v.) or shell construction in which the skin, together with its stiffeners or stringers, transmits the load. The longerons, generally four in number, may be made from wood, metal tubes etc., and are braced with ply, wooden or tubular struts and with wires to form a rigid structure.

LONGITUDINAL DIHEDRAL, see DIHEDRAL ANGLE & TAIL SETTING.

LONGITUDINAL STABILITY. There are two forms of longitudinal, or fore-and-aft, stability, called *static* and *dynamic*. An aeroplane is said to be statically stable if, when disturbed from a state of steady flight by, say, a gust of wind or a movement of the controls which may either increase or



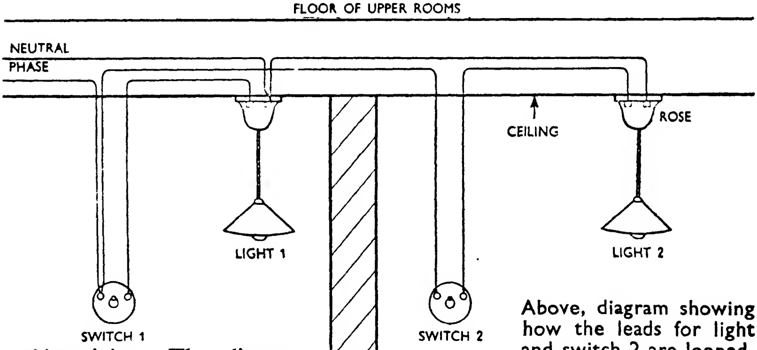
Typical graphs showing static and dynamic characteristics of an aeroplane.

decrease its speed, it tends to return to its original steady motion. It also has dynamic stability if, after a certain amount of oscillation, it actually does return to its former speed.

These two forms are best demonstrated by the curves of speed against time, as shown in the illustration. These curves show how an aeroplane can be statically stable but dynamically unstable, for it will be seen that although the aeroplane tends to return to its original speed, the oscillations, instead of damping out, as in section (B), go on increasing in amplitude, until the machine either stalls or goes into a nose dive, as shown at (C).

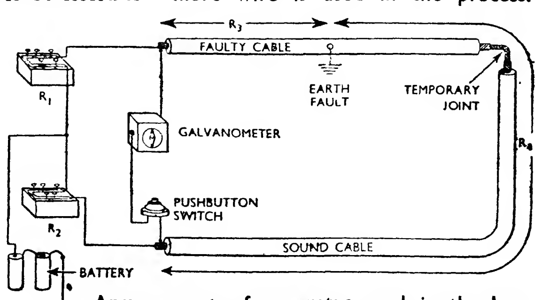
LOOP AERIAL. Another name for frame aerial (q.v.).

LOOPING-IN. An electric wiring system which avoids the necessity for making joints. The diagram shows the system applied to a domestic lighting installation.



Above, diagram showing how the leads for light and switch 2 are looped-in to switch and light 1 in order that the junctions may occur at points where clamping devices are available. In this way, no joints are needed in the run of wire but more wire is used in the process.

LOOP TEST. A method of finding the position of a fault in an electric line, in which the line to be tested is made to form part of a Wheatstone bridge. The circuit is illustrated in the accompanying diagram in which the resistance boxes R_1 and R_2 are adjusted until there is no galvanometer deflection when the push is pressed. Then $R_3 = \frac{R_1 R_4}{R_2}$ and from this relation and the resistance per yard of the cables, the position of the fault may be worked out. See WHEATSTONE BRIDGE.



Arrangement of apparatus used in the loop test in order to discover the fault in a cable.

LOOSE PIECES. In foundry work, the term refers to detachable parts of a pattern which are withdrawn from the mould either before or after the main pattern. These pieces are employed for projecting parts, which, if fixed to the pattern, could not be drawn without causing damage to the mould.

There are a number of different methods which may be employed for fixing loose pieces to the pattern, including wood or metal dowels, and dovetails. Loose pieces should be avoided if possible since they are liable to move when ramming, thus giving an inaccurate casting; this is

most likely to happen if the pattern has been used many times.

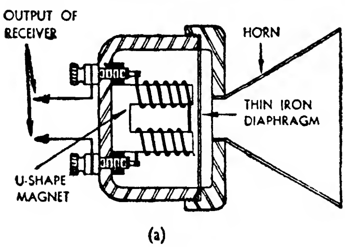
LORENZ BLIND-LANDING SYSTEM, see DIRECTION-FINDING.

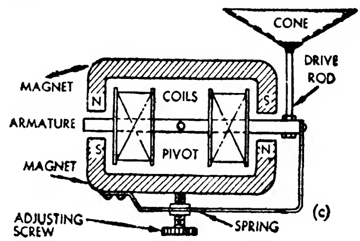
LOST MOTION. The loss of movement caused by incorrect fitting of linkage mechanism or wear in ball-and-socket joints etc. See BACKLASH.

LOUDSPEAKER. A device for translating electrical impulses into mechancial vibrations, i.e. sound. Early loudspeakers, see Fig. 1(a), consisted of a simple telephone earpiece (see TELEPHONE RECEIVERS) provided with a horn or trumpet. Such apparatus gives but poor quality reproduction, partly because the metallic diaphragm is too stiff to follow large-amplitude vibrations and partly because it tends to resonate (vibrate freely) at certain relatively high audio frequencies. The non-uniform magnetic field is a further cause of unfaithful reproduction.

An early attempt was made to overcome some of these drawbacks, the diaphragm being replaced by a soft-iron reed (see Fig. 1 (b)), the movements of which are transmitted by a thin rod to a diaphragm, usually of paper or buckram and conical in shape, large enough to set up a considerable air disturbance without the use of a horn. Some time later, an attempt to cure magnetic distortion was made in the balanced-armature speaker, shown at (c). In this, the moving part is again a soft-iron armature moving between four magnetic poles, with the result that the armature remains in a reasonably uniform field. Following this, a so-called inductor-dynamic loudspeaker, see Fig. 2 overleaf, was introduced.

Two soft-iron pieces A and B are attracted towards the two magnetic gaps. Normally the magnetic fields in these gaps are of equal strength with the result that A and B, rod and diaphragm, are at rest in the position shown. The coils associated with the magnetic circuit are arranged, however, so that a signal current makes the field across one gap stronger and across the other weaker. As a result the soft-iron block, A or B as the case may be, nearer the stronger field partly overcomes the opposition of the other and moves towards the magnet. When the signal current reverses, the other iron block is then attracted with the opposite result so that the movements of the bar and diaphragm correspond to variations in the signal current. With this arrangement the diaphragm is able to move in almost true piston-like manner and large-amplitude vibrations, giving good bass response, are possible. In this latter respect, the inductor loudspeaker is





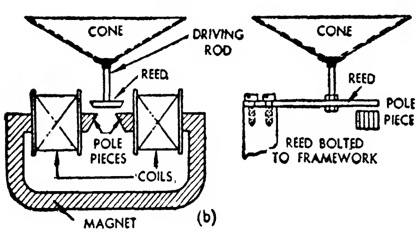


Fig. 1. Early type of loudspeaker (a) which was simply a telephone earpiece to which was attached a horn or trumpet. Section (b) shows an attempt to improve loudspeaker reproduction. A paper cone, fixed to an armature or reed, replaced a small iron diaphragm. Balanced-armature unit (c) overcomes some of the magnetic distortion in earlier types.

much superior to other types of moving-iron reproducers. The main drawback of such a device is the mass of the moving parts resulting in poor high note response.

Reproduction was revolutionized with the development of the moving-coil speaker which is now universally employed in all types of radio receiver and electrical sound-reproducers. The construction is illustrated in the sectional diagram, Fig. 2. Attached to the diaphragm is a light fine-wire coil free to move in the annular gap, which, being narrow, allows the coil to move in a relatively intense magnetic field.

The working principle is somewhat similar to that of the simple electric motor, the coil and diaphragm moving in a piston-like manner. The coil is prevented from fouling or touching the sides of the gap by the use of a "spider", a specially shaped piece of flexible material allowing to-and-fro, but not sideways, motion. To allow free movement the edge of the cone is attached to the chassis, either by a surround of soft leather or cloth or, as is more convenient with commercial units, through the medium of a series of corrugations moulded in the cone itself.

Generally, the coil is of low resistance or, more correctly, impedance, so that a low voltage of relatively large current is required. Output valves, however, provide small current and high voltage. Consequently, moving-coil loudspeakers are always coupled to the output valve by means of a suitable impedance-matching transformer. For optimum results the following formula can be used:-

$$N = \sqrt{\frac{\text{Optimum load of valve (in ohms)}}{\text{Impedance of speech coil (in ohms)}}}$$

where N is the transformer turns ratio; this in almost every case, will be *step-down.*

In many mains-operated receivers, the magnetic field in a moving-coil loudspeaker is not provided by a permanent magnet. It is convenient to have an electro-magnet, the winding of which may become the choke coil associated with the H.T. smoothing system. All loudspeakers not provided with a horn or trumpet must always be used in a cabinet, or must be fixed securely to a flat baffle (q.v.) or the bass reproduction will be severely attenuated due to the short air column separating the back from the front of the diaphragm.

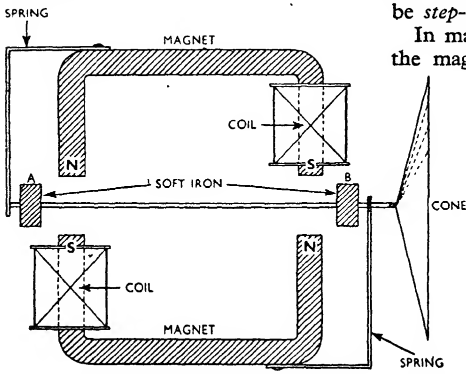
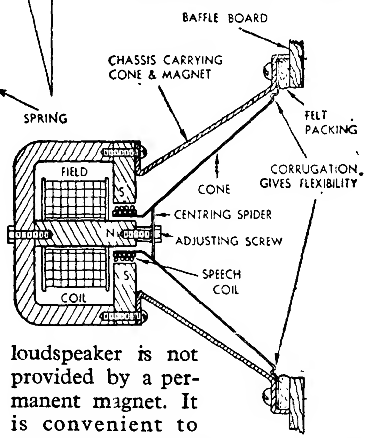


Fig. 2. Left, an inductor-dynamic loudspeaker; below, construction of moving-coil instrument. The field coil is often dispensed with, a permanent magnet being used instead.



Loudspeakers for special purposes, such as for public address work in the open, in theatre auditoria and so on, are often provided with horns with special directional properties and have to be very carefully designed and arranged, particularly where two or

more units can be heard simultaneously.

Again the piezo-electric crystal, although having desirable characteristics at high frequencies, has limited applications for loudspeakers in so far as it is somewhat unsatisfactory at low frequencies. It is, however, sometimes used in conjunction with a small diaphragm, when the device is known as a "tweeter" (q.v.).

A large-diaphragm loudspeaker for reproducing only the bass and middle register is often called a "woofer" (q.v.).

LOW FREQUENCY (L.F.). A term used in connexion with oscillations occurring relatively slowly or having low periodicity. Less broadly, it refers to the frequencies of speech and music and A.C. power mains. The terms audio frequency and power frequency respectively are, however, now more general.

LOW-PASS FILTERS, see FILTER.

LOW POTENTIAL, see EARTH.

LOW TENSION (L.T.). In radio apparatus, a term describing the relatively low voltage applied to the filaments or heaters of radio valves. The supply is usually derived from dry cells, accumulators, or, through a step-down transformer, from A.C. supply mains.

In automobile engineering, the vehicle lighting and charging circuit is said to be a low-tension circuit because the current passing through it is at a pressure of 6, 12 or 24 volts. The primary circuit of the ignition system is frequently referred to as the low-tension circuit to distinguish it from the secondary or high-tension circuit which varies in pressure between 4,000 and 15,000 volts. See MAGNETO.

LOW VOLTAGE. Synonym for Low Tension (q.v.).

L.T. Abbreviation for Low Tension (q.v.).

LUBRICANT. A substance, usually oil, introduced between surfaces having relative motion, in order to promote sliding and reduce friction. The correct selection of a lubricant is now a specialist's task, and the various marketers of such products have developed highly organized services giving advice on practically every kind of lubrication difficulty. Before the grade of a lubricant for a particular job can be determined, it is necessary to know the diameter and length of the bearing, the rotational speed of the shaft, and the loading or pressure per unit of projected area of the bearing surface. The amount of clearance also influences the type of lubricant.

For slow-running bearings under heavy loads, the oil should be heavy enough to obviate metal-to-metal contact, and yet not so viscous as to give rise to loss of power. The blending of oils, to promote better adherence to metallic surfaces, is another field for the specialist. Although industrial lubricants are usually derived from "straight" refined petroleum, animal or vegetable substances may be added—cylinder oils, for instance, may contain 4 to 6 per cent of acidless tallow.

There are various classes of mineral oils to which a fat saponified with an alkali has been added. These are known as greases, of which there are hard greases, medium greases, soft greases and non-fluid oils. They are used chiefly in places where oil would run out, e.g. in bearings for oblique shafts, or in ball or roller bearings for certain types of vertical motor.

LUBRICATION. The reduction of friction between two bearing surfaces having relative movement, by introducing oil, graphite, water or other lubricant (q.v.).

The chief methods of lubrication are as follows:—

(1) *Felt Pads*. These may be alone or in conjunction with grooves on the shaft.

(2) *Worsted Trimmings*. These act like the wick of an oil lamp, filtering the lubricant before feeding it to the bearing surface.

(3) *Ring Oiling*. An endless ring or chain is arranged to hang on the shaft, plenty of clearance being allowed; it dips into a bath of lubricant below the bearing; the rotation of the

shaft promotes slow rotation of the ring, which continually brings up fresh drops of lubricant.

(4) *Gravity lubrication.* Each bearing is provided with its particular pipe which is connected, with others, to an oil box forming a distribution manifold. Drip or wick feeds may be employed.

(5) *Forced-feed lubrication.* In this system a pump is employed to force the lubricant under a pressure of, say 15 to 40 lb. per sq. in. (for horizontal bearings) to the points at which it is required.

(6) *Flooded lubrication.* In this system, the bearing is lubricated by oil under a low pressure, the oil level being such as will flood the bearing at the point at which lubrication is to be applied, instead of relying on the pressure developed in the pump in a forced-feed system.

(7) *Gears* may be splash-lubricated or pressure-lubricated. In the former system, the teeth pass through an oil bath, the reservoir being in the base of the housing; in the latter a pressure, derived either from gravity feed or from a circulating pump, forces the lubricant on to the actual point of contact between the gear teeth.

Lubrication has an important effect on the life of a machine, particularly of

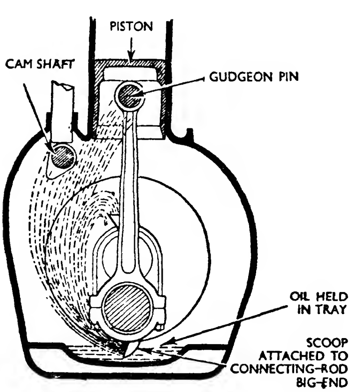


Fig. 1. Diagram of splash lubrication system showing how oil is thrown up by the big-end on to the camshaft, gudgeon pin and other parts of the engine.

the engine and transmission components of an automobile. The lubrication of gears is simple; all that is necessary is to maintain the oil at a certain level within the gearbox or back axle, whence it is circulated by the rotating members.

Engine lubrication. Several different methods of engine lubrication are outlined below. *Splash system:* where this method is employed the bottom part of the crankcase is filled with oil to a predetermined level indicated on the dipstick which rests in the oil and can be withdrawn for inspection purposes. It is marked at certain points, full, three-quarters full, half full etc., the level of the oil being shown by the oil on the stick. Dippers, or scoops, are fitted to the lower half of the connecting-rod big-ends and these, dipping into the oil as the crankshaft rotates, splash oil over all the moving parts within the crankcase.

Force-feed and Splash System. In the latter, troughs are provided under each cylinder into which the scoops on the connecting rods dip and splash the oil up to lubricate the connecting rod bearings, cylinder walls, camshaft etc. as shown in Fig. 1. An oil pump is used to force the oil through pipes to the main bearings of the crankshaft and to feed the troughs. *Force-feed system:* oil is forced by pump pressure to the crankshaft main bearings and through passages in the crankshaft to the big-end bearings.

Surplus oil overflowing from these bearings is thrown by centrifugal force on to the cylinder walls etc. This system is illustrated at Fig. 2. In certain types, the connecting rods are drilled and oil is forced up to the gudgeon pin. Troughs are not required in a full-pressure oil system and there are no scoops on the connecting rods.

In all lubrication systems it is important that the oil should be adequately filtered to prevent foreign matter getting into the main oil stream and setting up excessive wear. An oil gauge on the instrument panel is connected to the oiling system by a pipe-line. The gauge indicates the

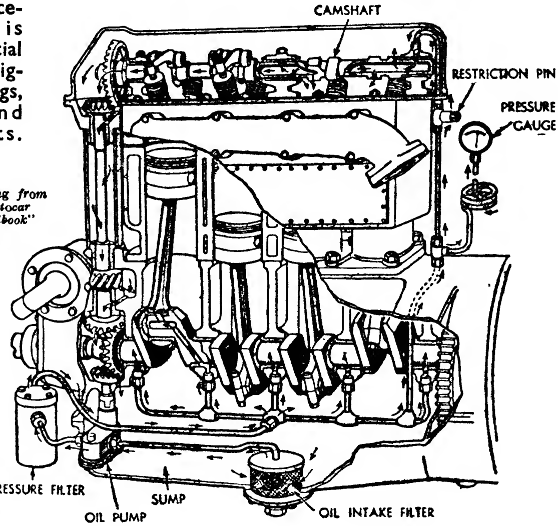


Fig. 2. In the force-feed system, oil is pumped through special pipes to valve gear, big-ends and main bearings, cylinder walls and other vital points.

Drawing from "Autocar Handbook"

pressure; if this is either high or low the causes should be investigated. A low pressure can be caused by leakages, broken oil pipes, worn bearings, or by a partially choked filter which starves the pump of a sufficient quantity of oil. A high pressure may result from a relief valve not functioning (see OIL-RELIEF VALVE), an incorrect grade of oil, or partially choked oil pipes or oil ways.

LUMEN. A unit of luminous flux. Its value is such that 4π, i.e. about twelve and a half, lumens are emitted by a standard candle. See LUMINOUS FLUX.

LUMINOUS FLUX. Symbol: F. The rate at which energy in the form of light is emitted from a luminous body.

LUMINOUS INTENSITY. Symbol: I. The amount of luminous flux per unit solid angle emitted by a point source of light. This may be visualized as the luminous flux passing through a square foot of area on the surface of a one-foot radius transparent sphere at the centre of which the point of light is placed. Since luminous intensity usually depends on position relative to the source, it is necessary to specify the direction from which the source is viewed. Synonym: Candle-power. See FOOT-CANDLE and LUMINOUS FLUX.

LUX. A unit of illumination. It is obtained when a luminous flux of one lumen falls perpendicularly on a square metre of surface. See FOOT-CANDLE, LUMEN and LUMINOUS FLUX.

MACHINE FINISH. The natural finish, also known as mill finish or M.F., of the paper as it leaves the paper-making machine without receiving special treatment. Usually a dull and fairly smooth finish is implied by the term.

MACHINE GUARD. A means whereby operatives are protected from being injured by the moving parts of machinery. Fixed guards of sheet-steel plate, or covers, fencing and the like can often be provided, but with such machines as guillotines and presses these are not always practical.

An efficient guard, while preventing accidents, does not impede output. The commonest form is the locking device to the operating lever setting the ram of a press in motion. This method is quite effective, but should not be used alone, as the real danger area is that between the tools, and this

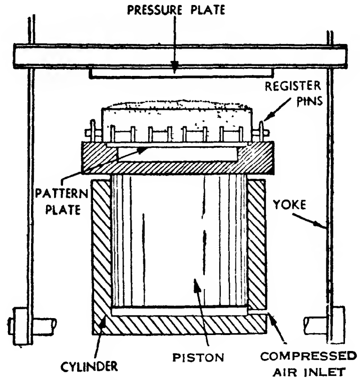
is left exposed. If the press or shears be set in continuous motion, the operator's hands can be trapped when he feeds the material. The same principle, operated electrically, is sometimes used and in this case the operator must use both hands when putting a machine into operation.

Mechanical safeguards are widely used, working in unison with the slide, cam, or crankshaft which transmits the working pressure, and are timed so that, as soon as the working stroke begins, the guard shuts off the danger area from any manual interference. The dropping-screen type of guard has given satisfactory service; in this a screen, consisting of a strong frame covered with wire mesh or a grid of bars, is hung high within the gaps, and pivots on two points at about the height of the operator. The screen is hung so that on the descent of the slide it will swing downwards and outwards, thereby closing the danger area. The screen is fully automatic, so that on the return of the slide it will also return to neutral position.

A similar principle may be used by hanging the screen on two pivots in front of the machine. Using fully automatic mechanical means (levers and connecting bars), the screen, on the downward stroke of the machine-slide, swings upwards and outwards thus pushing the operator away. Both these latter types are generally operated direct from the crankshaft and are timed to arrive at the safe position at the beginning of the working stroke. As they are fully automatic they will operate even if an unexpected repeat stroke occurs.

In 1939, a complete session of the National Safety First Association was devoted to press guarding. It was made clear that, in order to obtain perfect safety in all circumstances, means had to be found to prevent unexpected strokes from taking place.

MACHINE MOULDING. Methods of moulding in which ramming is done by machines instead of by hand. For small moulds, the patterns are usually mounted on a plate. The moulding box is held in position on



Detailed sectional diagram of an air-operated squeeze-moulding machine.

the plate by location pins. Sand is heaped on the pattern, smoothed and squeezed by means of a plate against which, as shown in the illustration, the moulding box is forced by compressed air, hydraulic or mechanical means.

In some machines the pattern may be lowered mechanically to avoid damaging the mould as it is lifted. To form a mould two pattern-plates are generally necessary. If possible these should be so designed that loose cores are avoided. As many patterns as possible should be fitted to a plate, runners and risers being provided to avoid cutting and possible damage to the mould.

In larger work, a plate pattern may sometimes be used, or one half of the mould rammed by machine and the other by hand. Owing to the greater depth of the moulding boxes, squeeze-moulding is not satisfactory. Instead, jolt-ramming or sand-slinging must be employed. In the first method the moulding box is placed on a platform which is lowered rapidly and brought suddenly to rest. This is done repeatedly, causing the sand to pack firmly round the pattern.

In the sand-slinging method, sand is shot into the mould, thus imitating by machine the moulder's method of throwing in sand by hand. In this way very even packing can be obtained. In machine moulding it

will be found that sand packs more firmly against horizontal than vertical faces. The methods are therefore unsuitable for very deep patterns. Loose packing will also be found underneath any projecting parts of the pattern. To avoid this, such places may be rammed first by hand, or special cores inserted.

MACH NUMBER. The ratio of the speed of any object through the air to the speed of sound under the conditions prevailing. The rate of propagation of sound through the air depends on air temperature only, so that under standard atmospheric conditions it is 746 m.p.h. or 1,120 ft. per sec. at sea level, falling to 664 m.p.h. or 974 ft. per sec. at 35,000 ft., the lower limit of the isothermal atmosphere, above which it remains constant.

MADAPOLLAM. A thin cotton fabric which is used to protect the exterior of wooden fuselages, wings etc. of an aeroplane. It is generally applied to the untreated surface with several coats of red dope (containing red oxide or oxide of iron) followed by a filler which is rubbed down, leaving a smooth surface for the finishing coats.

"MAGIC EYE". Also known as "Mystic Eye". A miniature cathode-ray tube, incorporating its own amplifier valve, used as an indicator for various purposes. In radio receivers incorporating automatic gain control, it is often employed as a method of showing when the set is accurately in tune. See CATHODE-RAY TUNING INDICATOR.

MAGNESIUM (Mg). Atomic no. 12; atomic wt. 24·32; a silvery-white metal, the lightest of the common metals, specific gravity 1·74. The melting point is 651 deg. C. and the boiling point 1097$\pm$3 deg. C. The metal is produced commercially mainly by the electrolysis of fused magnesium chloride or mixtures of magnesium chloride and alkali metal chlorides.

Pure magnesium is stable under ordinary atmospheric conditions, and is resistant to attack by alkalis and many organic compounds; it is attacked by acids, with the exception of hydrofluoric and chromic acids. Saline solutions, in general, corrode magnesium.

Magnesium has a limited capacity for cold work at room temperatures; but above 225 deg. C. it is amenable to forming operations. In the pure state, both cast- and wrought-magnesium possess a reasonably high elongation, but the mechanical strength is relatively low; when used in constructional and engineering applications it is therefore employed in the alloyed state.

The pure metal is used as an alloying addition to many metals, e.g. aluminium (M.G.5, M.G.7, Hydronalium-type alloys etc.), and also as a scavenger or deoxidizer in the preparation of many ferrous and non-ferrous alloys, e.g. steels, copper alloys and nickel alloys. In powder form, it is used to a considerable extent in the munition and pyrotechnic industries.

The most important use of magnesium is as the basis metal for the high-strength, light-weight alloys.

MAGNESIUM ALLOYS. The addition of alloying elements brings the mechanical strength of magnesium to a satisfactory figure. Magnesium alloys have now been developed for the manufacture of articles by die casting, forging, sand casting and permanent mould casting, and for work in extruded bars, plates and sheets.

The general range of composition of the alloys is: aluminium 2·5 to 12 per cent; manganese 0·1 to 1·5 per cent; zinc 0·5 to 3·0 per cent; remainder magnesium. Cadmium is sometimes added when forgings are required. The mechanical properties are shown in the table overleaf.

The heat treatment used in connexion with the sand castings is carried out in special ovens at temperatures of from 630 to 785 deg. F., after which the castings are allowed to cool in air. This increases resistance to shock; if the parts are not liable to shocks in service they are "solution

Magnesium Alloy For:—	Tensile Strength: lb. per sq. in.	Yield Strength: lb. per sq. in.
Sand castings, as cast	27,000	12,000
„ „ heat-treated and aged ..	38,000	18,000
Die castings	30,000	22,000
Hammer forgings	37,000	26,000
Extruded bars	42,000	30,000

heat-treated" and an ageing process (precipitation) is carried out at 350 deg. F.

MAGNET. A body which exhibits magnetic effects, either with or without electrical excitation. The former type is a permanent magnet and the latter an electromagnet. See Permanent Magnet, Electromagnet and Excitation.

MAGNETIC CIRCUIT. A closed path, which is traversed by a number of lines of magnetic flux. The circuit is often broken to form an air gap (q.v.). A diagram of the field arrangement of a machine is given under Pole.

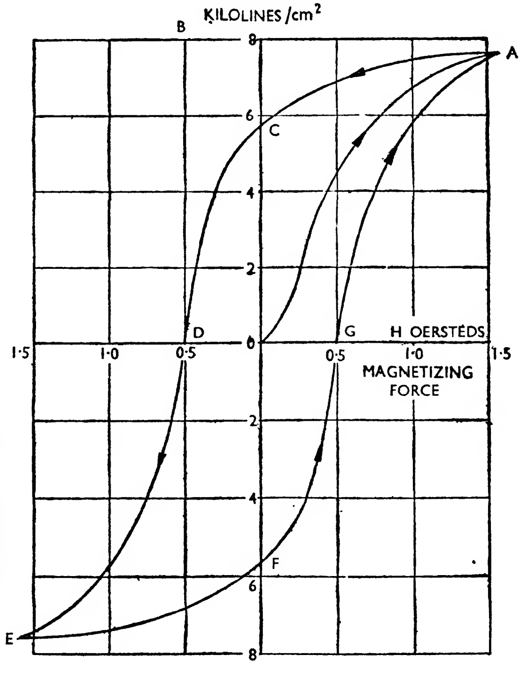
MAGNETIC EFFECTS. The phenomena by means of which the presence of a magnet may be detected. For example, the earth's magnetic field is detected by its effect on a compass.

MAGNETIC FIELD. The space within which the magnetic effects of a magnet or a current are observable. See Magnetic Effects.

MAGNETIC FLUX. Symbol: Φ. The number of lines of magnetic force crossing a particular area or produced by, for example, a coil. Flux is measured in maxwells or lines. The lines are purely imaginary but it is often convenient to regard them as elastic threads. See Line of Magnetic Force.

MAGNETIC FLUX DENSITY. Symbol: B. The magnetic flux crossing a unit area (sq. cm. or sq. in.) taken at right-angles to the lines of magnetic force. A density of one line per square centimetre is called one gauss. Synonym: Magnetic Induction. See Gauss and Magnetic Flux.

MAGNETIC HYSTERESIS. The phenomenon which causes



Area of loop ACDEFG is proportional to hysteresis loss. In electrical machines all possible steps are taken to reduce this area for types of steel to be used where alternating magnetic fields are encountered.

changes in the magnetic state of certain materials to lag behind changes in the magnetizing force. The figure shows the effect of subjecting a sample of iron to a magnetizing force which is first increased (OA), then decreased (AC), rises in the other direction (CDE) and is finally brought back (EFG) to its original maximum value (A). Subsequent reversals of magnetic force produce repetitions of the loop ACDEFGA.

This figure is known as a hysteresis loop and represents an expenditure of energy. The size of the loop depends on the value A taken as maximum. If this point represents saturation, then OC is the remanence and OD the coercive force. See COERCIVE FORCE and SATURATION.

MAGNETIC INDUCTION. Synonym for magnetic flux-density.

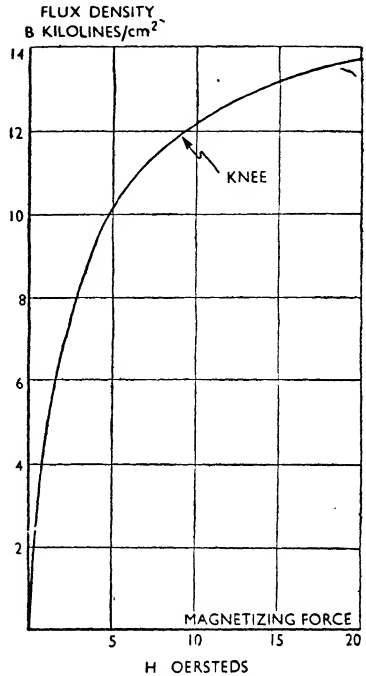
MAGNETIC LEAKAGE. The part of the magnetic flux which follows paths other than those in which its presence is desired. In a salient-pole electrical machine about 20 per cent of the flux produced in a pole fails to enter the armature, and merely leaks to an adjacent pole.

MAGNETIC SATURATION, see MAGNETIZATION CURVE and SATURATION.

MAGNETIZATION CURVE. A graph showing the relation between the magnetic flux-density in a magnetic material and the magnetizing force. A typical curve is shown in the diagram. Flux density is usually expressed in kilogauss or thousands of lines per square centimetre while magnetizing force may be in oersteds or ampere-turns per centimetre or per inch.

At first the curve is nearly a straight line, but it begins to bend at about 10,000 gauss to form the "knee". Thereafter it flattens out so that a very large increase in H is needed to produce a relatively small increase in B. When this state is reached saturation is said to occur. See GAUSS and OERSTED.

MAGNETIZING FORCE. The magnetomotive force per centimetre of path in a magnetic circuit. It is



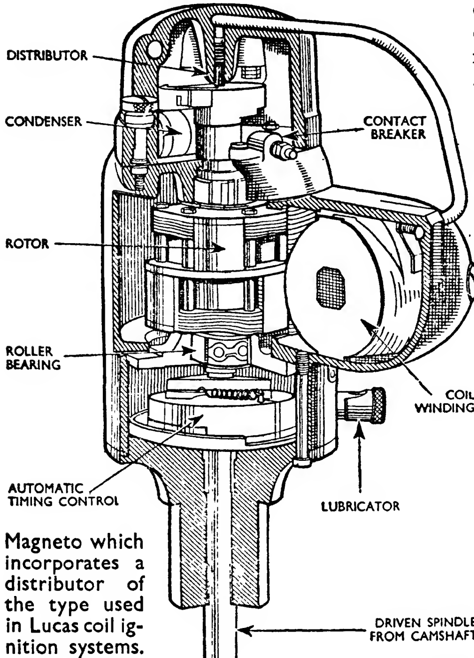
In design of electrical machinery, the magnetization curve B-H is fundamental. For most purposes, the value of B is taken near the knee of the curve.

commonly expressed in oersteds or ampere-turns per unit length. See AMPERE-TURN and OERSTED.

MAGNETO. A combined generator and transformer of high-tension electric current; sometimes used in the ignition system of internal-combustion engines.

An "H" armature is wound on the usual laminated stampings and, being driven from the engine, rotates between the poles of a powerful permanent magnet. At normal engine speed this armature will generate a comparatively low voltage, say 6 to 12 volts. Wound over this low-tension armature is a secondary of many thousands of turns of wire, so that, if the current flows in the low-tension armature, there will be a high secondary e.m.f.

A machine of this type, as shown, generates alternating voltages and it



Magneto which incorporates a distributor of the type used in Lucas coil ignition systems.

would seem that no interrupter would be necessary, since the alternating currents flowing in the primary are continually changing in their amplitudes. But the secondary e.m.f. can be considerably increased by fitting the primary with a contact-breaker and condenser as with coil-ignition systems and, in addition, there will be a very high secondary e.m.f. at each break of the primary circuit. It will be seen, therefore, that a magneto is very like a rotating induction coil (q.v.).

MAGNETOMOTIVE FORCE (m.m.f.) Symbol: F. The product of the magnetizing force and the distance along a magnetic flux-path or, if the magnetizing force varies, the sum of such products. It is measured in gilberts. The magnetomotive force produced by a coil carrying an electric current is $\frac{4\pi}{10}$ times the ampere-turns.

MAGNETO-STRICTION. A change in the dimensions of a sample of a magnetic material which is caused by the application or removal of a magnetic field.

MAGNETRON. A radio valve in which the electron flow from cathode to anode is controlled by a magnetic field. One of its chief applications is the generation of very high radio-frequency oscillations.

MAGNIFICATION FACTOR. A term sometimes used in place of "amplification factor" (see RADIO VALVE). Also used in connexion with the "Q factor" of a coil or circuit. See "Q".

MAGNOLIA, see CANARY WOOD.

MAHOGANY. A rich, reddish-brown wood which, with the exception of the highly-figured varieties, is easily wrought, and, owing to its stability, durability and appearance, is widely used. *Cuban* mahogany is the most superior but supplies are scarce, with the result that *Honduras*, a slightly inferior though excellent wood, is frequently used for the same purposes. The roey grain gives it a golden-red appearance.

Similar species are imported from Central and South America. West African species form the bulk of the supplies on the English market, and are distinguished by the source of origin, or by an alternative name.

Well-known substitutes are Toon, Lauan, Espavé, Coromandel, Gaboon, Meranti, Makore, Sapele, Seraya and Thitka. These are, generally speaking, excellent woods and are used for superior joinery. See TIMBER.

MAIN BEARING (Auto. Engineering). One of the bearings which support the crankshaft of an internal-combustion or other type of engine. Bearings are usually made in two halves and parts in contact with the journal are faced with alloy metal to reduce friction and wear. It is essential that, in all bearings, adequate

provision for lubrication be made and that the correct lubricant be used.

MAINS. A system of conductors for distributing electrical power. See DISTRIBUTOR, FEEDER and RING MAIN.

MAINS RECEIVER. A radio receiver which derives all its power from public or private supply mains. See RADIO RECEIVER.

MAINS UNIT. Another name for Battery Eliminator (q.v.).

MAKE-READY. A printing term used to describe the preparation of formes or blocks on the machine prior to printing. This treatment is necessary because of the unavoidable fractional differences in the height of types and pictures.

To get a good impression, the printing surfaces must be dead level, and to ensure this the printer often has to paste varying thicknesses of paper on to the bottom of the type or block to bring it up to the required general level.

MAKORE, see MAHOGANY.

MALLEABLE CAST-IRON. A variety of cast-iron which is cast white preparatory to undergoing either the white-heart or the black-heart process.

In the *white-heart* process annealing consists of packing the castings in an oxidizing medium such as haematite iron-ore and heating for a considerable period at temperatures up to 950 deg. C. The carbon present in the iron is largely burnt out but a small proportion is deposited as rounded nodules of temper graphite. The castings, after this treatment, are relatively soft and of good strength.

The period of annealing required is considerably affected by the composition of the white cast-iron employed, unduly high amounts of sulphur or low proportions of silicon tending to prolong the process excessively. A suitable composition is: combined carbon, 2·50 to 3·50 per cent; sulphur, 0·10 to 0·20 per cent; silicon, 0·5 to 0·75 per cent; phosphorus 0·05 to 0·08 per cent; manganese 0·20 to 0·40 per cent. The mechanical-test requirements given in British Standard Specification No. B.S.309, for White-Heart Malleable-Iron Castings, are Ultimate Stress 20 tons per sq. in. and Elongation 5 per cent.

Black-Heart. With the exception of the annealing treatment, the details of manufacture are the same as those given for Malleable Cast-Iron (White-Heart). The annealing process consists of packing the castings in an inert material and heating for a prolonged period. The carbon is not removed, but is almost entirely converted to temper carbon. For this reason, flake graphite should be entirely absent in castings intended for this process, whereas in the white-heart process a small proportion of graphite does no harm. As the process is thus largely one of graphitization, elements tending to promote or retard this action must be completely controlled. Silicon may with advantage be as high as one per cent, provided that fully-white castings can be obtained with such a composition.

Sulphur should not exceed 0·08 per cent or the process of graphitization will be prolonged considerably. Chromium, like sulphur, is also harmful. The mechanical-test requirements given in British Standard Specification No. B.S.310 are Ultimate Stress 20 tons per sq. in. and Elongation 7½ per cent.

MALLEABLE IRON. See WROUGHT-IRON.

MALTOSE, see CARBOHYDRATES.

MANGANESE. Mn; atomic no. 25; atomic wt. 54·93. A grey metal harder than pure iron; melts at 1242 deg. C.; density 8·0. It occurs as pyrolusite, MnO_2, braunite, Mn_2O_3, and other minerals. It is extracted by reducing the ore with carbon in the electric furnace or by the thermit process. Manganese forms five oxides, MnO, Mn_3O_4, Mn_2O_3, MnO_2 and Mn_2O_7.

It is available as spiegel, containing 15 to 17 per cent of manganese, ferro-manganese, containing 30 or more per cent of the metal, metallic manganese, cupro-manganese etc. These materials are used to introduce proportions of manganese in a wide range of alloys. Thus all ordinary steels and cast-iron

contain 0·4 to 1·0 per cent of the metal and special alloy irons and steels may contain as much as 15 per cent.

Manganese is also used in many non-ferrous alloys, including manganese bronze, copper-nickel resistance alloys and a number of aluminium and magnesium alloys.

MANGANESE BRONZE. The trade name of a group of special brasses containing small proportions of tin, iron, aluminium, nickel and manganese. The term bronze is incorrectly applied to these alloys since they contain at the most only a small amount of tin. A more suitable name is high-tensile brass. The alloys are used for making castings, forgings and rolled sections. Five grades of casting alloy are specified in B.S.208: 1924 in the first table below.

These grades show a gradual increase in strength as the proportions of the minor elements are increased. In these alloys tin, in amounts exceeding 0·5 per cent, is liable to form weak and brittle films at the grain boundaries, so reducing both strength and ductility. For this reason it is generally excluded entirely from classes 4 and 5.

Two grades of high-tensile brass, suitable for bars, sections and forgings,

SPECIAL BRASS CASTINGS

Class	1	2	3	4	5
Copper per cent	54 min.	54 min.	54 min.	50 min.	50 min.
Zinc per cent	bal.	bal.	bal.	bal.	bal.
Total metals other than copper and zinc per cent *	5·0 max.	5·0 max.	8·0 max.	10·0max.	13·0max.
0·15 per cent Proof Stress, Tons per sq. in.	12 min.	15 min.	17·5 min.	20 min,	25 min,
Ult. Stress, Tons per sq. in.	28 min.	32 min.	34 min.	38 min.	45 min.
Elong. per cent	25 min.	18 min.	15 min.	15 min.	12 min.

* i.e. Tin, iron, manganese, aluminium and nickel.

HIGH-TENSILE BRASS BARS, SECTIONS AND FORGINGS

B.S. No.	1001	1002
Copper per cent	56·5 to 62·0	56·5 to 62·0
Total elements other than copper and zinc per cent *	7·0 (max.)	7·0 (max.)
Aluminium per cent	0·2 (max.)	—
Zinc per cent	Remainder	Remainder
0·1 per cent Proof Stress Tons per sq. in.	12 min.	14 min.
Ult. Stress Tons per sq. in.	30 min.	34 min.
Elongation per cent	20 min.	18 min.

*These elements include tin, iron, nickel, aluminium, lead and manganese. Lead must not be present in amounts exceeding 1·5 per cent.

are specified in B.S.1001 and 1002: 1941, the composition and minimum mechanical properties being as given in the table at the foot of the previous page.

High-tensile brasses possess a remarkable resistance to corrosion, the cast alloys being thus suitable for marine propellers, pump parts etc. and the wrought alloys for shafts running in contact with sea water.

MANGANIN. An alloy of copper and manganese. Its outstanding characteristics are its relatively high electrical resistance, as compared with copper, and its almost negligible temperature coefficient.

MAN-MADE STATIC, see INTERFERENCE.

MANŒUVRABILITY (Aero. Engineering). The ability of an aeroplane to carry out various evolutions in the air, such as rolls, loops etc. It cannot be defined in absolute terms; thus one cannot say that such and such an aeroplane has ten units of manœuvrability. It is possible, however, to compare the manoeuvrability of two aeroplanes, partly qualitatively, by the feel and harmony of the various controls, and partly quantitatively, by comparing the times etc. for various evolutions; for example, the time to bank to a given angle, with a certain force applied to the control column at some speed, or the minimum radius of turn etc. It is thus possible to set up a standard of manœuvrability.

MANUAL TELEPHONY. A system of telephone exchange operation in which connexions between subscribers are effected manually. See AUTOMATIC TELEPHONY.

MAPLE. A hard, compact, lustrous wood, not liable to splinter; in some respects resembling beech. It is chiefly used for flooring which is subjected to hard wear, and for kitchen fitments etc. The ornamental varieties, such as bird's-eye, blister and fiddleback, are esteemed for furniture, fittings and other purposes. See TIMBER.

MARBLING (Painting). The processes employed to imitate in paint the characteristic colour and structure of natural marbles. For successful marbling a study of the type to be represented is more useful than the copying of one small sample; then, with intimate knowledge of pigments and their behaviour with various media and thinners, a procedure is evolved which will reproduce a similar appearance with the minimum of labour. Marbling is generally worked upon a white ground, every advantage being taken of the possibilities of transparent pigments in creating an impression of depth. Most marblers develop their own technique, experiment being the best teacher. See SIENNA.

MARBLING (Printing). A typical decoration applied to the edges of commercial books. End papers may also be produced by this means, and the two should harmonize. Although often of hackneyed pattern, the process lends itself to great flexibility of treatment in artistic hands. Formerly, fine books were marbled and then gilded over, the effect being a choice pattern when the book was open.

Marbling is produced by throwing inks mixed with ox-gall into a bath of viscous fluid. The inks spread according to the proportion of ox-gall into which they are mixed. Spreading and contraction can thus be controlled. Combs of various pitch and other simple tools of individual choice are used to distribute the inks. The surface to be decorated is sized with alum and brought into contact with the floating pattern which makes firm adhesion.

Patterns may be similar but no two are exactly alike. Where large quantities of end papers are required, the effect can be imitated by lithography.

MARKING KNIFE. A tool, chisel-shaped at one end and pointed at the

Double-ended type of marking knife used in woodwork for scoring lines.

other, which is used on the bench for marking-out woodwork. The point is used for pricking-off positions and the

sharpened end for scoring lines preparatory to sawing.

MARKING-OFF TABLE. A massive cast-iron bench-plate, generally supported on wooden chocks and accurately levelled. The upper surface, which is made as flat as possible, provides a datum level in the marking-out or scribing of straight lines, arcs, centres of holes etc., upon castings or forgings to be machined.

Such tables are particularly useful for work to be machined on milling, drilling, or planing machines. The forgings or castings are covered with a coat of whitewash over the whole region of their surfaces where marks have to be made; when the whitewash is dry, the marker-off can begin his work.

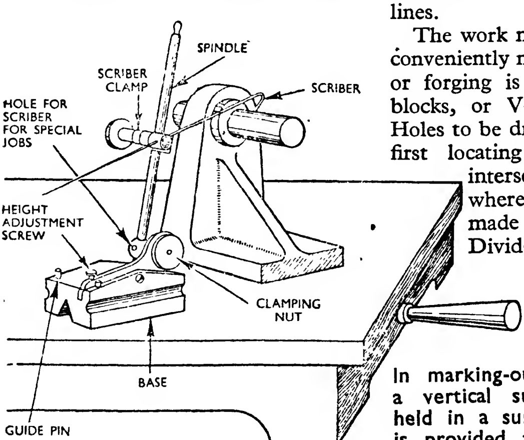
Using actual drawings or blue prints, he lays out each item to size, making all scribed lines clear and distinct; except when they are required for finished surfaces, he traces their courses with occasional centre pops, in case the whitening should subsequently get washed off, as may easily happen in, say, a radial drill with a copious supply of cutting fluid. The degree of accuracy to be aimed at in marking off will be governed by the nature of the work, much of which may be confined to fairly rough castings.

Care must be taken in setting out, to see that the item marked off can afterwards be properly machined to its finished dimensions, especially if it is barely large enough, here and there, in its rough state, to allow an adequate margin for machining. See MARKING-OUT.

MARKING-OUT. The marking-out, or laying-out, in engineering, of work to be machined is performed on the marking-off table, as shown, from the drawings or blue prints. Generally the best plan is to choose a surface from which to work towards other surfaces. It is also convenient, when many lines have to be scribed, to start from a base line which is drawn first because, should the item have to be moved during marking-out, the base line will then form a useful datum from which to check or re-level.

Every possible use should be made of the bench plate, or table surface, a scribing block (q.v.) being adjusted to the height given on the drawing, so as to enable horizontal lines to be scribed. For great accuracy a height gauge (q.v.), incorporating a vernier attachment, is sometimes used. All horizontal lines having been scribed, the vertical intersecting lines are begun. To scribe them, either a surface already machined or a suitably positioned angle plate or square may be used. Alternatively a starting point can be chosen and measurements from it marked-off with dividers. A bevel protractor can be used for oblique lines.

The work may sometimes be more conveniently marked-off if the casting or forging is supported on parallel blocks, or V-blocks, on the table. Holes to be drilled are marked-off by first locating the centre, by the intersection of scribed lines, where a small pop mark is made with a centre punch. Dividers are then set to the correct radius and a circle of the true diameter is scribed around the centre



In marking-out horizontal lines on a vertical surface, the scriber is held in a surface-gauge. Adjustment is provided for varying its height.

just obtained. The pop mark is then enlarged to facilitate the location of the drill when starting.

In many castings it happens that lines may intersect where there is no metal to receive a pop mark, e.g. at a cored hole. In such cases a piece of wood is used to form a kind of bridge, a small sheet of tin being affixed to the wood; the intersection of the lines is then located on the tin, which can receive a light pop mark. The slight movement of a core in a mould may result in a hole being out of position in a casting. The casting can sometimes be saved from rejection if another surface can take sufficient machining to compensate for the departure of the core from its correct position; a trial layout is then advisable in order to find what margin, if any, is available.

MARTENSITE. The constituent responsible for the great hardness of quenched steels. Under the microscope it appears as needle-shaped crystals interlacing at 60 deg. to each other. This structure is due to the deposition of carbide along the cleavage planes of the original austenite grains.

The hardness of martensite increases with the amount of carbon present in the steel. With 0·9 per cent carbon a hardness (q.v.) of 900 V.P.N. is possible. The formation of martensite on quenching is accompanied by severe internal stresses which may be relieved by tempering at up to 300 deg. C. without any great loss of hardness, but with a very considerable increase in toughness.

MASONRY. The preparation and erection of structures in natural stone. The finest effects in architectural construction have been obtained in masonry, and it will continue in use for outstanding monumental, public and commercial buildings and churches, and for the restoration of such buildings.

Building stones include limestone, sandstone and granite for constructional work, and marble for monumental and internal decorative purposes, for wall linings and special flooring surfaces. Among the better-known stones are:- *Limestones*: Ancaster, Bath, Clipsham, Ham Hill, Ketton and Portland, the last-named being favoured for architectural effect and much used in London and various parts of the country. *Sandstones:* West Yorkshire Stones (Bramley Fall type), Craigleith, Darley Dale, Forest of Dean, Mansfield and Robin Hood. *Granites*: from Aberdeenshire, Argyleshire, Cornwall, Westmorland and Ireland. In the past a very large quantity was imported from Norway, Sweden and the Channel Islands, the latter being chiefly used for road material, kerb stones, setts etc.

Weathering is the process of change under external agencies, wind, rain, dust, frost and vegetation. Some stones weather to produce good effects, particularly limestones; fine sandstones resist the chemical effect of impure atmospheres better than limestone but become aesthetically unattractive. Granite is very durable and its use is justified where great strength and durability, or resistance to abrasion, are required.

Natural bed is the formation bed of the stone. In the closely grained and homogeneous stones the direction of the bedding planes does not show clearly or interfere with the working, but where lamination is visible all sedimentary stones—viz., those that have been laid down in the form of layers—should be placed in the wall of a building so that the natural bedding planes are parallel to the courses of the wall or, that is to say, at right-angles to the pressure. In arches the bed should be radial; in undercut projecting cornices, on edge, and at 90 deg. to the face of the wall, which prevents the detachment of layers from the underside of the overhanging mould.

Types of Masonry. Walls may be built in rough stones as quarried with a "random" arrangement, or the stones may be roughly squared to assorted sizes and built-in courses. Stone may be dressed, in uniform depth, and built as ashlar, and may be prepared in structural and decorative

forms in door and window openings, plinths, cornices, chimney stacks, arches, domes, niches, vaulting, retaining walls, bridges, piers, buttresses etc.

Craftsmen who work stones to pattern are called "banker masons," and those who build walls of rough stones are called "wallers," whilst those who set wrought stonework are called "fixers."

In modern masonry, stones are worked largely by machinery, but considerable hand-work is still indispensable. *Machines* include saws, planing and moulding machines, diamond and carborundum cutting being general. *Hand Tools* include hammers, axes, chisels, saws, combs and setting-out and testing tools.

In large modern steel-framed structures, stone has been much used for facing, usually with a brick backing, the walls receiving intermediate support from the steel stringers at floor levels. Projecting cornices on comparatively thin walls call for special ties and support, usually in the form of light-steel sections, hook bolts, cramps and the like. Bonding and setting of stone follow the same principles as in brickwork, except that sizes are not uniform but conform to the architectural details.

MASS. The amount of matter in a body. It differs from weight because weight depends on the distance of the body from the centre of the earth and is different at sea-level from what it is at the top of a mountain. In the metric system the unit of mass is the gram.

MASS BALANCE. The distribution of the mass of a wing or control surface of an aeroplane so as to prevent flutter. It is achieved by disposing the mass of the wing etc. in such a way that the sum of the products of each element of mass and its distance from the flexual axis and its distance from the wing root or control surface hinge is zero. By flexual axis is meant the line about which the bending takes place.

This condition may be obtained by adding a weight or weights, known as mass-balance weights, to a suitable part of the structure. In the case of a control surface, weights are rigidly fixed to the surface forward of the hinge line as shown in the accompanying illustration of a rudder.

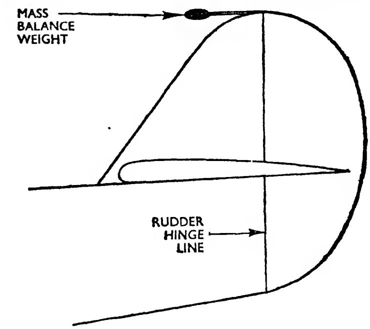


Diagram showing mass-balance weight attached to the rudder of an aeroplane. Note that weight is situated well forward of the rudder hinge-line.

MASSICOT, see LEAD.

MASS SPECTROGRAPH. An instrument for recording the change of direction of a positively charged particle when passing through an electric and a magnetic field. It enables the mass of an isotope to be determined with an accuracy of about 1 in 20,000.

MASTER OSCILLATOR. In a radio transmitter, a very constant frequency oscillator which determines the operating frequency of the station.

MASTIC. A soft resin, soluble in turpentine, used in making varnishes (q.v.).

MASTIC ASPHALT, see ASPHALT.

MASTIC CEMENT. A mixture of fine sand, litharge and red lead worked into a stiff paste by the addition of boiled linseed oil; used for pointing brickwork, particularly round window and door casings. The cracks and joints are well raked out, dusted and painted with boiled linseed oil before filling with the paste.

MATCHING. The coupling of one circuit to another in such a manner that the maximum energy transfer shall occur. In A.C. work, this is usually accomplished by means of a

transformer; for example, matching a loudspeaker to an output valve. See IMPEDANCE and LOUD-SPEAKER.

MATRIX (Building), see CONCRETE.

MAXWELL. A unit of magnetic flux equal to one line. See LINE OF MAGNETIC FORCE.

MAXWELL'S LAW. An electromagnetic law relating to the behaviour of circuits. It states that a single current producing flux tries to alter the shape of the electric circuit in such a way as to permit the greatest number of lines of force to thread it, and that two circuits try to dispose themselves so that the greatest number of lines of force thread both of them.

MEAN AERODYNAMIC CHORD (M.A.C.), see MEAN CHORD.

MEAN CHORD (Aero. Engineering). The pitching moment acting on a small portion of the wing of an aeroplane is a function of its chord and area; thus, for a rectangular wing, the total pitching moment on it depends on its chord (which is, of course, constant) and its total area. For wings other than rectangular, i.e. straight tapered, elliptic etc., the chord varies along the span; it is thus necessary when making calculations involving the pitching moment to have an average, or mean, chord value which will represent that for the whole wing.

We can thus define the mean chord of a wing as an imaginary chord of such a length, and in such a position, that it can be used to represent the whole wing when calculating pitching moments.

It is also called Aerodynamic mean chord (A.M.C.) or Mean aerodynamic chord (M.A.C.).

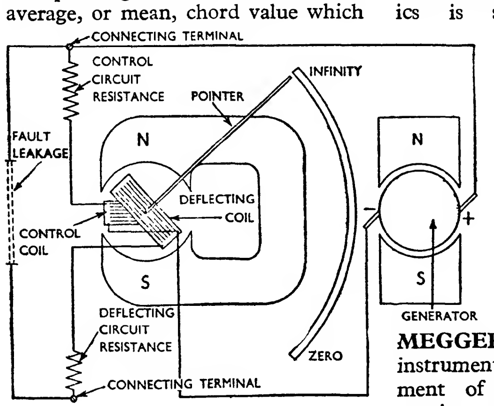
MEAN-SPHERICAL CANDLE-POWER. The candle-power of a source of light, averaged in all directions. The averaging may be performed mathematically from a number of single measurements of candle-power, or by means of a uniformly reflecting enclosure such as a hollow sphere, in which case only one measurement is needed. See CANDLE-POWER.

MECHANICAL PRESSES, see COINING PRESS, DOUBLE-ACTION PRESS, HYDRAULIC PRESS and SINGLE-ACTION PRESSES.

MECHANICS. The science of forces and mechanisms. *Statics* deals with forces in equilibrium and bodies at rest; *Dynamics* with bodies in motion. *Hydrostatics* concerns liquids at rest and *hydrodynamics* liquids in motion. *Pneumatics* deals with gases. Mechanics is sometimes divided into mechanics of solids (both statics and dynamics), and mechanics of fluids (liquids and gases).

MEDIUM. The liquid content of paint in which the pigment, or solid base, is suspended.

MEGACYCLE. A term used in electrical engineering meaning one million cycles. See CYCLE.



In this circuit diagram of a Megger Tester, the external connexions are shown dotted; the remainder are enclosed in one box. Deflection depends upon relative currents in the coils which act in opposition to each other.

MEGGER TESTER. An electrical instrument for the direct measurement of insulation resistance. It consists essentially of a hand- or motor-driven generator and a direct-reading ohmmeter contained in the same case. The circuit arrangement is given in the diagram.

If a circuit contains capacitance the

reading will not be steady unless the generator speed is constant. For this reason some models are fitted with an automatic clutch which slips when the speed reaches a predetermined value.

MEGOHM. An electrical unit equal to one million ohms. See OHM.

MEEHANITE. A variety of grey cast-iron made by melting iron charges, usually containing a considerable proportion of steel, in a cupola and adding a small quantity of calcium-silicide to the molten metal as it enters the ladle. The process is patented. Meehanite is made by a number of different foundries in Britain under license issued by the International Meehanite Co., Ltd., London.

The addition of calcium silicide produces little effect on the composition of the iron other than a slight increase in the silicon content. The main effect is one of inoculation, the ladle addition promoting graphitization, so that the resulting iron contains finely divided and uniformly distributed graphite. The iron so produced is stronger and tougher than could be made from similar charges without inoculation.

A number of different grades of Meehanite are available varying in tensile strength from 16 to over 25 tons per sq. in. In addition to the inoculation treatment, small proportions of alloying elements such as nickel, copper and molybdenum are generally added to the higher-strength grades.

MELTING RANGE. The difference between the temperature at which an alloy is completely liquid and that at which it becomes completely solid. On an equilibrium diagram (q.v.) it is the vertical distance between the liquidus and solidus curves.

MENDING-UP. A term used in foundry work to denote the process of repairing any damage caused to a mould in withdrawing a pattern. It is usually accomplished by pressing facing-sand to shape with the fingers and smoothing-off with a small rectangular piece of wood.

MERANTI, see MAHOGANY.

MERCURY. (Hg). Atomic no. 80; atomic wt. 200·61. Mercury (quicksilver) is principally obtained from mercuric sulphide, HgS (cinnabar), found in Spain, Italy and elsewhere. It is a silver-white metal, liquid at ordinary temperatures, density 13·39, m.p. −38·9 deg. C., b.p. 356·9 deg. C. Mercury dissolves many metals, and the solutions are known as amalgams; some of these are definite compounds, some are of varying composition and are mixtures. Cadmium amalgams are used in dentistry.

Mercury forms two classes of compounds, the mercurous compounds, in which it is monovalent, and the mercuric compounds, in which it is divalent. Mercurous chloride, HgCl (calomel), is largely used in medicine. Mercuric chloride, $HgCl_2$ (corrosive sublimate), is an important drug; mercuric oxide, HgO, is an antiseptic known as red precipitate.

MERCURY-ARC RECTIFIER. The mercury-arc rectifier is one of the simplest and most convenient methods of converting A.C. to D.C. It consists of a glass bulb or a steel tank from which the air has been removed and into which a quantity of mercury has been introduced. The

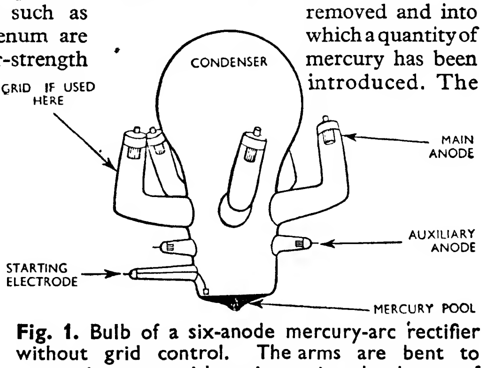


Fig. 1. Bulb of a six-anode mercury-arc rectifier without grid control. The arms are bent to economise space without increasing the danger of arcing between anodes. Each anode is connected to one of the secondary windings of, in this case, a three- to six-phase type transformer.

glass bulb variety is illustrated in Fig. 1. The mercury pool at the bottom of the bulb forms the cathode while the anodes take the form of shaped blocks of graphite mounted at the remote ends of the bent arms. There may be any number of anodes, but the most usual numbers are 3, 6 and 12.

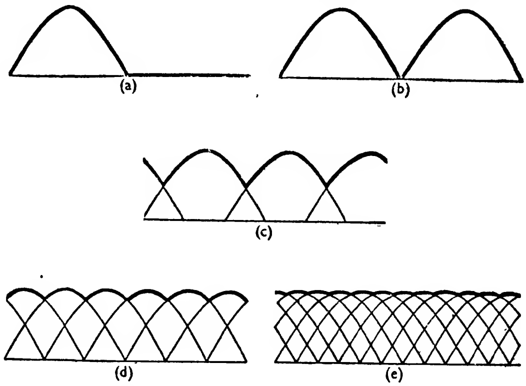


Fig. 2. Thickened lines represent waveform of D.C. voltage of a rectifier if voltage drops are ignored; (a) is half-wave, (b) full-wave, (c) three-phase, (d) six-phase and (e) twelve-phase. In all cases the length of the base line is one cycle. The reduction in ripple as the number of phases increases is clearly shown.

When the rectifier is first switched-on an electromagnet draws the end of the spring arm of the starting electrode into the mercury and then releases it. An arc is thus caused which ionizes enough of the mercury vapour, which is always present, to enable the auxiliary anodes to fire. These auxiliary anodes are in operation all the time the rectifier is energized and their function is to provide enough ionized vapour to allow the main anodes to fire when they are ready.

It is characteristic of the mercury-arc that it can carry a relatively high current with a small drop of voltage (about 20 volts). This may be compared with the behaviour of a "hard" type of thermionic valve, that is, a valve from which practically all the air has been evacuated and into which no other gas is admitted. Like the hard valve, the soft valve is a rectifier. Current is able to pass only from anode to cathode, so that the mercury pool is the positive D.C. terminal.

When the rectifier is working there is a bright spot of light on the mercury surface. This spot darts about in an erratic manner and marks the cathode end of the arc. The intense heat vapourizes some of the mercury, but it is cooled in the large domed top of the bulb, condenses and runs back into the pool again.

The anodes are connected to the 3, 6 or 12-phase secondary winding of the transformer, the neutral point of which forms the D.C. negative terminal. Unless special circuits are used, only that anode which at any time is the most positive to the cathode carries current, so that the arc commutates or changes from one anode to the next as the secondary-phase voltages of the transformer rise and fall. If the rectifier is examined with a stroboscopic device (see STROBOSCOPE) the arc appears to move slowly from one anode to the next.

A useful mental picture of the operation of the rectifier may be obtained by imagining the anodes to be automatic switches which open and close in sequence according to the rule mentioned above. It is both possible and advantageous to arrange for two anodes to carry current at the same time as in the double three-phase working of a 6-anode rectifier.

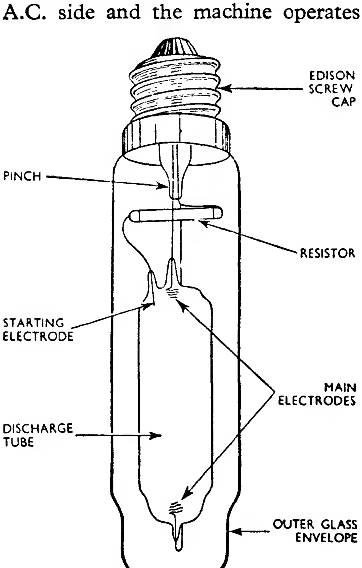
The D.C.-voltage waveform is given, very nearly, by the outline of the tops of the sine waves, so that the more phases there are, the more nearly does the waveform approach the ideal straight line. This point is illustrated in Fig. 2. If necessary the

D.C. may be smoothed by means of circuits similar to those used for the D.C. supplies to radio sets, but this precaution is not needed unless there is danger of interference with communication circuits.

The voltage of a mercury-arc rectifier shows a steady drop as the load is increased, the drop at full load being of the order of 6 per cent, but in certain cases there is, in addition, a sharp fall at very light loads.

By fitting additional electrodes, known as grids, between the anodes and the bulb, the operation of the rectifier may be altered. When these grids are supplied with suitable voltages they have the effect of delaying the change-over from one anode to another beyond the point at which it would normally take place. As this delay is increased, that is to say as the ignition is retarded, the D.C. voltage falls; gradually at first and then more steeply, and if appropriate circuits are provided, the voltage becomes negative.

In this condition, power may be fed backwards from the D.C. side to the A.C. side and the machine operates



Mercury-vapour lamp of the 250-watt type which must be fixed vertically.

as an inverter. In this connexion it should be noted that power is the product of current and voltage, so that a reversal of either of these quantities signifies a reversal of power. In the case of the rectifier it is the voltage which reverses; the current cannot do so. When operating inverted, there must, therefore, be a source of D.C. voltage in the D.C. circuit, of such polarity that it helps the current round the circuit in the original direction.

MERCURY-DISCHARGE LAMP, see MERCURY-VAPOUR LAMP.

MERCURY-VAPOUR LAMP. An electric lamp wherein a discharge takes place through an atmosphere of mercury vapour. The light is blue-green in colour. The diagram shows the construction. Synonym: Mercury-discharge lamp.

MERCURY-VAPOUR RECTIFIER. A power-rectifying valve into which mercury vapour is introduced for the purpose of obtaining special characteristics. See GAS-FILLED VALVE and RECTIFICATION.

MERZ-PRICE SYSTEM. A protective system for electrical equipment in which the secondary windings of current transformers are opposed. In normal circumstances the opposing voltages are equal but in the event of a fault they are unbalanced and the resulting current operates relays which cause the circuit-breakers to be opened. See RELAY.

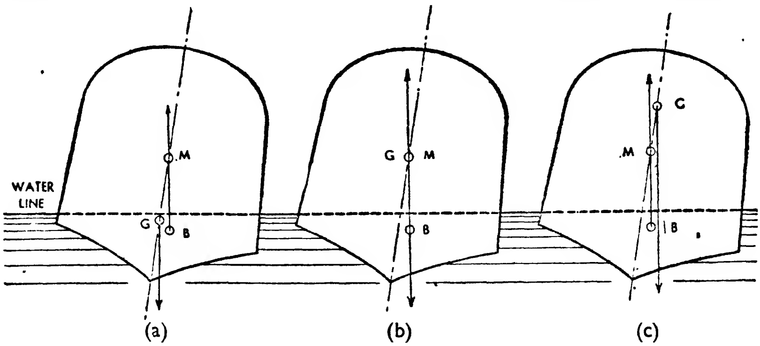
MESH CONNEXION. Synonym for delta connexion (q.v.).

MESOMERISM. A term used to denote a structure in which the valency of some of the elements seems to be split up into fractional parts that are not whole numbers. The structure, also known as *Resonance*, cannot be shown by a diagram in which a single line denotes a valency of 1, a double line a valency of 2, and so on.

MESQUITE, see IRONWOOD.

MESSMATE, see EUCALYPTUS.

METACENTRE. The point at which a vertical line drawn through the centre of gravity of a body floating in equilibrium in a liquid will meet a second vertical line drawn through the centre of buoyancy when the body



METACENTRE OF FLYING-BOAT HULL

Diagram showing, left, metacentre above centre of gravity (stable); centre, coincident with centre of gravity (neutral); right, below centre of gravity (unstable).

is slightly displaced from its equilibrium position.

Consider a flying-boat hull or a seaplane float heeled over through a small angle as shown at (a) in the illustration. Normally the centre of gravity is on the centre line; if it is at G, the weight then acts vertically down through G. The upward thrust due to the water displaced, or buoyancy, is equal to the weight, and acts vertically up through B, the centre of buoyancy. The point M at the intersection of the centre line of the hull and the vertical through B is called the transverse metacentre.

So long as the metacentre is above the centre of gravity there will be a couple tending to restore the hull to an even keel, and it is statically stable. If the metacentre coincides with the centre of gravity as in (b) it will be neutrally stable and remain in any position. However, should the metacentre be below the centre of gravity as in (c) the hull will be statically unstable and tend to capsize.

In a manner similar to the above there is a *longitudinal* metacentre.

METAL LEAF. Thin sheets of alloys of various metals which vary in colour from silver to copper. They are extensively used in decoration of theatres etc., to obtain inexpensive metallic finishes. They are applied upon the tacky surface of almost-dry japan gold-size. After application they require a protective coating of white shellac in solution or clear cellulose lacquer to prevent oxidation. See DUTCH METAL, GILDING and GOLD LEAF.

METALLIC COATING. A relatively thin deposit of one metal on the surface of another, usually for improving resistance to corrosion or for decoration. There are several methods by which metallic coatings may be formed:

Electro-deposition. The deposition of a metal coating by electrolysis of a suitable solution in which the article to be coated is made the cathode. Many metals, as well as alloys, may be deposited, e.g. silver, nickel, copper, brass, tin, zinc, chromium etc.

Hot-dipping processes. The work, with a suitably prepared surface, is dipped into a bath of the molten metal; on removal, a thin film of the molten metal adheres to the work. Tin and zinc are the best-known examples of this, and vast tonnages of sheet-metal products are treated in this way. The metal coating may alloy with the base metal.

Cementation processes. In these the coating metal in powder form, with suitable additions, is rotated in a drum with the articles to be coated. The whole drum and its contents are heated to a high temperature, care being taken to exclude air in order

to avoid oxidation of the powder. Zinc is used in this way in the process known as sherardizing (q.v.) and aluminium in the calorizing process. Only small articles can be coated in this way, though special drums are available for coating pipes.

Spraying processes. In these the metal is fed into a suitable pistol in the form of either wire or powder, and is then melted in an oxy-hydrogen or oxy-acetylene flame and atomised in an air blast. There is also a process using molten metal instead of wire or powder. This method has the advantage that it can be used to treat, *in situ*, articles which may be too large to handle by other processes. Almost any metal may be sprayed if it can be obtained in a suitable form and will melt in the oxy-acetylene flame. See CHROMIUM PLATING, ELECTRO-DEPOSITION, GALVANIZING and METAL SPRAYING.

METALLIC INKS. Used in printing as a modern alternative to bronze powders for producing a metallic effect on printed sheets. Previously, powder and liquid medium or vehicle were supplied separately to the printer to be mixed immediately before use, the metallic effect being obtained by application as a normal printing ink.

The inks are now supplied mixed ready for use and require no adjustment. The consistency is thinner than that of ordinary printing ink, and this allows the orientation of the flocculent particles in flat formation before the drying of the vehicle, thus giving maximum reflective power. The paper should therefore also be smooth and allow little vehicle penetration. They are made in copper, red, peacock-blue, green, purple and pale tints for letterpress and gravure. Lithographic silver inks give good results and possess good working properties, but owing to the higher specific gravity of the gold powder greater difficulty is experienced in formulating a suitable vehicle for gold inks for lithographic printing.

Covering power is good, but perhaps slightly less than that of the dusted powder. Apart from health reasons (absence of the atmospheric pollution and highly objectionable nature of bronze powder) metallic inks have the advantage that overprinting can be done satisfactorily. Paper should be chosen very carefully; if it is too absorbent, penetration of the vehicle leads to dusting or rubbing of the powder. The ideal paper allows a very slight penetration of the varnish, so that the leafing of the metal then produces maximum brilliancy.

METALLIC STATE. Pure metals in the solid state seem to be composed of positively charged atoms surrounded by layers of electrons or negative units of electricity. The electrons readily transmit an electric current, a characteristic of the metals.

Pure metals are often brittle and need to be alloyed with some other element in order to become strong and elastic. The other element added for this purpose has an atom or ion that occupies a greater or less space than that of the pure metal, and this has the effect of making areas that are not so closely packed. These areas can resist a sudden strain and afterwards return to their normal state; they act almost like buffers or springs, and the alloy becomes less brittle.

METALLIZED RESISTOR. A type of resistor in which the resistance element is sprayed or deposited on an insulating rod.

METALLURGY. A term which originally meant the art of extracting metals from their ores. Today, however, its meaning has been extended to cover not only the production of metals, but also the systematic investigation of the properties of metals and their alloys.

In a works engaged in the production of metallic articles, the metallurgist serves several functions, the most important being the exclusion of unsatisfactory material from service. Metals and their alloys may suffer from a variety of faults. The metallurgist must be able to detect these faults, apply the necessary corrective treatment when possible, or take action to ensure that the trouble does

not occur again. In addition he is concerned with the improvement of existing alloys to meet duties of increasing severity and with the development of new and better alloys.

The beginner in metallurgy must first appreciate that metals, in the solid state, are crystalline substances possessing definite freezing points at which they change directly from the liquid to the solid state (see COOLING CURVE). Mixtures of two metals do not as a rule freeze completely at a definite temperature, but over a range which varies with the respective proportions of the two metals. This effect is conveniently recorded in the form of an equilibrium diagram, (q.v.), of which three main types are described, other more complicated diagrams being merely combinations of two or more of these types in one diagram.

In addition, these diagrams indicate the different phases which may be present, at any given temperature, in any particular alloy of two metals; and what possibilities exist of obtaining enhanced properties by heat-treatment. Many commercial alloys are composed of only two metals; many others may be so considered, although they may actually contain three or more metals. For example, gunmetal, composed of copper, tin and zinc, may be regarded as essentially an alloy of tin and copper. The effect of the zinc is small compared with that of tin and may consequently be neglected. It will be seen, therefore, that a knowledge of how to interpret these diagrams will be of great value to the student.

METAL RECTIFIER. A unilaterally conducting device. At one time a term applied exclusively to the copper-oxide rectifier, which functions by virtue of the fact that, when a thin film of copper oxide is formed on a surface of metallic copper, the resistance offered by such a film is low for currents flowing in one direction and high for currents going the opposite way. A simple element of this kind will withstand only a few volts, and it is generally necessary to employ a number of such elements in series. See SELENIUM RECTIFIER.

METAL ROUTING. The process of removing unwanted metal from the surface of a sheet or plate by means of a revolving cutter. The practice of cutting or routing metal at a cutter speed of 24,000 r.p.m. is comparatively new, but it has achieved great importance in the aircraft industry during the past few years.

The major advantage of routing is that sheet metal can be cut out to any shape without difficulty. The general method is to bolt a sheet of material to the top side of a board 1 in. thick (called the jig), while on the underside is fixed the required profile plate to which the sheet is to be cut.

The jig is then put on the routing-machine table, and the profile plate makes contact with a pin in the table and the cutter over the table entering the sheet. As the jig is moved around the pin, the cutter generates a profile in the sheet equivalent to the profile in the underside of the jig. This method is used for small work and employs a fixed-head machine.

An alternative method, that of fixing the work and moving the cutter head, is generally adopted for large-sheet work, say, more than 2 ft. × 2 ft., and the machine employed is of the radial-arm type.

Routing is suitable for aluminium, alclad and dural sheet up to $\frac{5}{16}$ in. thickness, and for sheet brass and sheet copper, but is not practical for steel. Sheets up to 4 ft. wide and of any length up to 30 ft. can be conveniently handled on the router.

A major advantage of routing over press tools is the simple and inexpensive jig equipment required. Nevertheless, as care is required in the design and production of the jigs, users should enquire of the makers for information and advice.

METAL SPINNING. An inexpensive method of producing hollow bodies from sheet metal by means of a lathe. The general equipment of a spinning shop includes a lathe of some sort, spinning tools (metal-shod bars of sufficient length to manipulate the

maximum gauge material to be used), and material for making chucks. While new spinning lathes are available, capable of very fine work, considerable use is made of ordinary lathes, suitably adapted.

The spinning chuck (normally built-up to form with wood) is screwed into the lathe mounting, a blankholder is secured in position, and with a spinning tool T-piece guide on the bed the lathe is ready for service. The blank to be formed is persuaded over the chuck by means of the tool and a degree of force exerted by the operator while the machine is in motion.

Operators find it very difficult to describe accurately the degree of force they should exert on the spinning tool to give the right amount of forming pressure (enough to deform but not enough to cause fracture). The direction of application is at right-angles to the axis of the lathe, the lever being pivoted in the rest by the operator, where two arms can simultaneously apply force and direction. Some authorities consider it advisable to vary the metals used for tools—thus, brass gives good results in spinning steel, while steel tools can be used on brass, copper or aluminium.

The earliest metals to be spun were pewter, copper, brass and silver, but the requirements of the aircraft industry for cowlings and similar parts have demanded spun aluminium components, with very successful results. Mild steel, too, is easy to spin since it can be given a physical structure which will withstand tearing during spinning. The nickel alloys have been spun successfully, but as such material work-hardens quickly it must be annealed frequently and carefully.

METAL SPRAYING. The application of metallic coatings by projecting a finely divided spray of the molten metal on to the surfaces to be coated. There are three main types of pistol in use for the spraying of metals. The first makes use of a wire of the metal to be sprayed, which is fed continuously into a blow-pipe flame: High-pressure compressed air is introduced around the flame, so that as the wire melts it is disintegrated and blown on to the surface being coated. In some cases an inert gas such as carbon-dioxide is used instead of compressed air, to prevent excessive oxidation of the metal particles.

In the second type of pistol, metal powder is directed into a suitable high-temperature flame and similarly projected on to the article being coated. In the third method molten metal is sprayed directly from a container by a process similar to that used in paint-spraying technique, the molten metal being fed to the spray pistol by gravity.

Metal-sprayed coatings are highly porous, and consist of mixtures of metallic and oxide particles. Good adhesion of the sprayed coating is difficult to secure unless the surface is thoroughly clean and has for preference been shot-blasted prior to spraying.

A good many metals can be successfully sprayed, including zinc, aluminium, tin, copper and mild steel. The coatings are used both for protective purposes and for the building-up of work parts. They can be applied to both metallic and non-metallic surfaces.

METAL TRIM, see SKIRTING.

METASTABLE STATE. A metal is said to be in the metastable state if it remains liquid below its true melting point. In such circumstances, solidification occurs only if the liquid is inoculated with a crystal, or crystals, of the metal. The metastable range of temperature extends only a few degrees below the melting point. Below this range, crystallization occurs spontaneously without the introduction of any nuclei. The metal is then said to be in the *labile state.*

These terms may also be used with respect to the melting and freezing points of alloys. A similar case is presented by transformations that occur in the solid state, the temperature at which a transformation occurs on heating being always higher than

that obtained during cooling. See COOLING CURVE.

METER. In general a measuring instrument. In electrical engineering the term is often restricted to integrating meters, such as a domestic-supply meter, as opposed to indicating instruments such as an ordinary ammeter or voltmeter.

METHYL ALCOHOL. A colourless liquid, CH_3OH, also known as wood spirit. With a characteristic smell it boils at 64·5 deg. C., and is poisonous. It was formerly made by the distillation of wood, but is now made by passing a mixture of carbon monoxide, CO, and hydrogen over a catalyst made of a mixture of zinc oxide and chromium oxide. It is readily oxidized by air in the presence of a catalyst, so making formaldehyde, which is used in great quantities in the manufacture of modern plastics.

METHYLATED SPIRIT. The ordinary violet methylated spirit sold in shops consists of about 90 volumes of ethyl alcohol, about 9½ volumes of methyl alcohol, about ½ volume of pyridine and a little mineral naphtha coloured with methyl violet.

Other varieties of methylated spirit are used in industry for making varnishes and lacquers and for blending with hydrocarbons to make fuels suitable for internal-combustion engines.

METRIC SYSTEM. The system of measurement used by scientists all over the world, in which the unit of length is the metre, equal to 39·37 inches. The centimetre is 0·3937 inches; the kilometre is 1000 metres, 0·62 of a mile. The unit of mass is the gram or gramme, 15·43 grains or 0·035 of an ounce avoirdupois. A kilogram is 1000 grams, 2·20 lbs. The unit of time is the second. The unit of heat is the calorie, the heat required to raise the temperature of 1 gram of water from 15 deg. to 16 deg. C.

The great calorie, K calorie, or food calorie, is 1000 calories. The unit of volume is the litre, the volume occupied by one kilogram of water at 4 deg. C. and 760 mm. of mercury (atmospheric pressure); 1 mm., a millimetre, is a thousandth part of a metre. The litre is practically 1000 cubic centimetres, and is 0·264 of a gallon. The thermometer scale used by scientists is the Centigrade scale, in which the melting-point of ice is 0 deg. and the boiling-point of water is 100 deg.

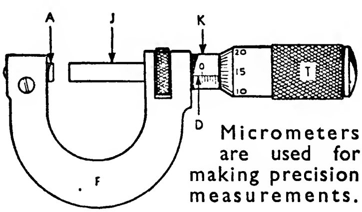
M.F. (Printing), see MACHINE FINISH.

MHO. Symbol: ℧. A unit of electrical conductance which, in D.C. work, is the reciprocal of resistance. Thus a circuit which permits one ampere to flow when one volt is applied has a conductance of one mho.

MICRO. A millionth part of, as in microfarad.

MICROFARAD. An electrical unit of capacitance. It is equal to one millionth of a farad (q.v.).

MICROMETER. An instrument for enabling the sizes of components to be measured to a high degree of accuracy. Micrometers are made in a variety of forms, the commonest being



Micrometers are used for making precision measurements.

shown in the illustration, but all employ the same vernier principle.

At one extremity of a frame F is a fixed stop A serving as a point from which all measurements are made. An adjustable spindle J carries a knurled "thimble" T attached to one end. The thimble has enough clearance internally to allow it to move over a sleeve K fixed to the frame F. Graduations are marked on both sleeve and spindle. The portion of the spindle J which passes through the frame F is threaded, the pitch being 40 threads per in., the frame being bushed and tapped to the same thread. One complete turn of the thimble T will thus advance or bring back the spindle by $\frac{1}{40}$ i.e. 0·025 in.

The scale marked on the sleeve K

is graduated so that one small division corresponds to one complete turn of thimble T; four small divisions thus indicate four-fortieths or one-tenth of an inch. The thimble T has a chamfered edge round which the graduations are marked, the circumference being divided into 25 parts. If the thimble is rotated through *one* division on its periphery, it means that the spindle moves laterally through $\frac{1}{25}$ of $\frac{1}{40} = \frac{1}{1000}$ in.

Actual micrometer readings are thus obtained by multiplying the number of complete sub-divisions showing on the sleeve by 25 and adding the number of circumferential divisions. In the illustration, for example, 6 divisions are showing on the sleeve, whilst division 14 on the rim of the thimble is against line D on the sleeve. The reading is thus $(6\times25)+14=150+14=164$ thousandths, or 0·164 in.

MICROPHONE. A device by which sound waves are made to produce voltage or current variations of the same frequencies and waveforms. A piece of apparatus to convert sound energy into electrical energy.

THE CARBON MICROPHONE functions by virtue of the fact that the resistance of a mass of carbon granules depends upon the pressure applied to the carbon. When sound waves strike the diaphragm, pressure variations which are followed by the diaphragm are transmitted to the granules. As the degree of "packing"

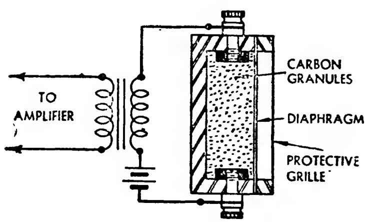


Fig. 1. Diagram showing construction of a "transverse-current" carbon microphone. The diaphragm is usually a thin sheet of mica and the carbon granules are contained in an insulating housing; solid black disks shown connected to terminals are carbon blocks in contact with the granules.

alters, so does the electrical resistance of the device, and the current variations correspond to the original sound waves.

Such a microphone, as shown in Fig. 1, is in itself an amplifier, since the amount of electrical output controlled by diaphragm movement is greater than the sound power needed to operate the diaphragm. The carbon microphone also has certain disadvantages, the chief of which are a steady background noise, or hiss, owing to random changes of resistance of the mass of granules, and instability. It is, therefore, used where sensitivity is essential but is seldom employed in high quality work.

THE CRYSTAL MICROPHONE makes use of the piezo-electrical property of certain crystals, chiefly Rochelle salt, in which mechanical stress due to sound waves is converted into electrical output. Such a microphone is simple, it has a fairly even frequency response and a high output impedance. Attempts have been made to step-up the stress on the crystal by mechanical methods, but, while, by this method, sensitivity can be increased, the frequency response is not very uniform.

THE RIBBON or VELOCITY MICROPHONE is, in some respects, similar to the moving-coil microphone. The "diaphragm" is a flat piece or ribbon of light metal alloy free to move in a magnetic field, and is acted upon by the sound waves. The force exerted upon the ribbon by a sound wave is proportional to frequency and particle velocity.

The velocity microphone has marked directional characteristics, of which advantage can be taken to minimize unwanted noises and reverberations.

It is quite simple, has an excellent frequency response and is essentially of low output impedence. It cannot, however, be used close to a source of sound, as "boomy" reproduction would result from over emphasis of the lower frequencies.

THE MOVING-COIL MICROPHONE, as shown in Fig. 2 on the opposite page,

is, in construction, very similar to its counterpart, the moving-coil loud-speaker. As the diaphragm, and hence the coil, moves with the sound wave, voltages are induced in the coil and fed through a matching transformer to an amplifier. It has somewhat greater sensitivity than the condenser microphone and is of low impedance output.

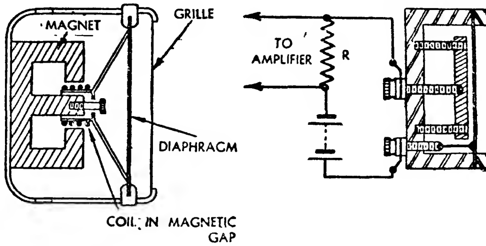


Fig. 2 (left). Moving-coil microphone. The coil is free to move in an annular gap provided by a permanent magnet. The connexions, omitted for the sake of clarity, are taken from the ends of the coil and are brought out to suitable terminals. **Fig. 3** (right). Condenser microphone which operates as described in text.

THE CONDENSER MICROPHONE, see Fig. 3. is a condenser in which one plate is fixed and the other is a diaphragm operated by sound waves. A polarising potential of several hundred volts is applied to this condenser and the movements of the flexible diaphragm produce a corresponding change in the D.C. potential difference across the high resistance as indicated in the diagram.

A condenser microphone can be designed to have relatively stable characteristics and even response over a fairly wide frequency range. Its sensitivity is comparatively low and an amplifier, preferably very close to the microphone, is essential.

MICROPHONICITY, see MICROPHONIC NOISE.

MICROPHONIC NOISE. The term referring to effects produced by mechanical vibration in a radio valve. Movements or vibrations of valve electrodes produce variations in anode current and may give rise to unwanted modulation of a signal that is being amplified. Rigid construction of modern valves reduces this effect to a minimum, but it can often be still further reduced by supporting valves on shock-proof mountings.

Another microphonic effect particularly noticeable in radio-frequency amplifiers and oscillators is due to mechanical vibration of the components themselves, particularly coils, variable condensers and wiring. Here again, rigid construction and shock-proof mounting usually effect a cure.

MICROPHONY. Also called microphonicity. See MICROPHONIC NOISE.

MICRO-WAVES. Radio waves having a very short wavelength, usually of the order of centimetres, corresponding to very high frequencies.

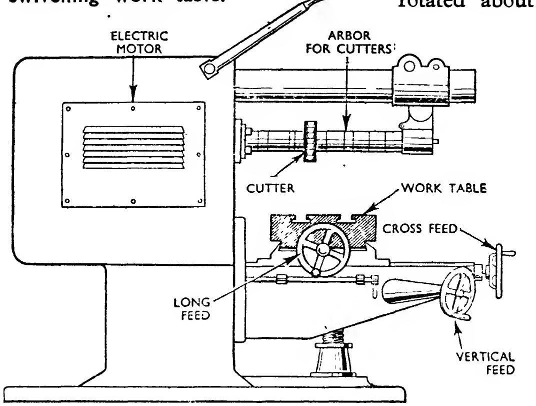
MILD STEEL. Low-carbon steel. Although the upper limit is not clearly defined, it may in general be taken as about 0·25 per cent carbon. It would not be unfair, also, to say that there is a lower limit as well—about 0·12 per cent carbon.

These low-carbon steels are more often designated as dead-mild, soft, dead-soft, deep-drawing, or Armco iron. Alternatively, this material may be classed as steel with a maximum tensile strength of about 30 tons per sq. in. It should further be noted that the term is also restricted to straight-carbon steels.

The usual grading into soft, mild or hard steel refers to the carbon content. In general the carbon content governs the tensile strength of plain carbon steels; as the carbon rises the ductility decreases but the tensile strength increases. In these days of alloy steels the terms soft, mild or hard steels are too vague and loose, being capable of too wide an interpretation for modern practice.

MILLER EFFECT. The effect on the grid circuit of a valve produced by the voltage fed back from the anode

Milling machine equipped with horizontally swivelling work table.



through the capacity between the grid and anode.

MILL FINISH, see MACHINE FINISH.

MILLI. A thousandth part of, as in milliampere.

MILLING MACHINE. A device for imparting a desired shape to components by bringing them into contact with a revolving tool or cutter.

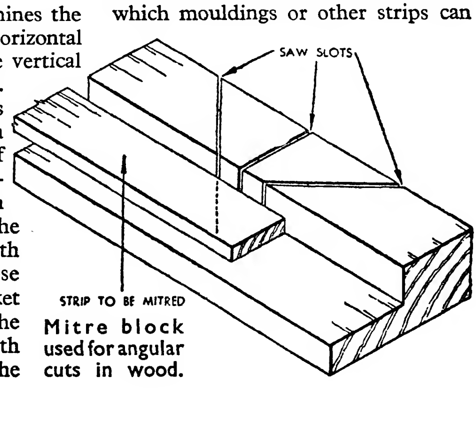
Milling is one of the most important machine-shop processes, since it covers the production of a very wide variety of surfaces: flat or curved surfaces and grooves or slots, as well as splines, are all produced on milling machines (see above). For such a range, milling machines are naturally of several types, and may be classified into two main divisions, horizontal and vertical.

In horizontal milling machines the milling cutter is carried on a horizontal arbor (spindle); whilst in the vertical type the arbor is also vertical. Horizontal milling machines are usually built up from a massive casting, usually of rectangular box-section, forming an upright column which also constitutes the base of the machine. This is provided with vertical slides on one side; these carry the "knee", the bracket carrying the worktable. The knee can be moved both towards and away from the vertical column, as well as to and fro laterally, past it. In addition it can be rotated about a vertical axis, thus permitting the feeding of the workpiece past the cutter in any required direction. The arbor is carried at one end by a cantilever overarm, supporting a yoke in which the bearing is located; the other end of the arbor is fitted by a coned joint into the driving spindle. To prevent undue springiness, during heavy cuts, the overarm and its yoke may be braced to the knee of the machine.

All modern machines are provided with change-speed gearboxes, giving a range of spindle speeds for all kinds of work. The cutters may be made solid or, for large surfaces, they may have the teeth inserted separately.

MISFIRING. Sometimes a combustible charge drawn into the cylinder of an internal-combustion engine does not ignite owing to some defect in the ignition system or, perhaps, to an incorrect ratio of petrol and air. This mixture is then forced out of the cylinder unexploded, during the exhaust period, and is known as a misfire.

MITRE BLOCK. A jig or fixture on which mouldings or other strips can



Mitre block used for angular cuts in wood.

be held while they are sawn at the correct angle for a mitre joint, usually an angle of 45 deg. The illustration shows the usual type for woodwork. The slots guide the saw while the strip to be cut is held firmly against them. See JOINTS.

MITRING, see JOINTS.

MIXER. Another name for frequency changer (q.v.).

MIXTURE CONTROL (Aero. Engineering). A device, such as a variable-orifice jet, or an additional controllable air supply, fitted to the carburetter to reduce the richness of the mixture under certain conditions. It can be either manually controlled, or, as is more usual nowadays, automatic in action.

A mixture control is required for two reasons. In the first place, when the aeroplane climbs, the density of the air falls with increasing altitude, and owing to the metering characteristics of the carburetter the mixture increases in richness, and it is necessary to weaken it to maintain the correct functioning of the engine.

Secondly, all aero engines when running at or near full power are supplied with more petrol than is required for complete combustion of the air, so that, to obtain economy under cruising conditions, it is necessary to weaken the mixture.

MIXTURE STRENGTH. Ratio of fuel-gas to air in an internal-combustion engine (q.v.).

M.M.F. Abbreviation for Magneto-motive Force.

MODIFICATION. A process applied to aluminium-silicon alloys, containing 12 to 14 per cent silicon, to improve their mechanical properties. It consists of treating the molten alloy, immediately before pouring, with a small proportion of sodium metal or caustic soda. The effect is to refine the structure of the alloy. In particular the size of the silicon particles is greatly reduced. No trace of sodium can subsequently be detected in metal so treated.

MODULATION. The process of producing a wave some characteristic of which varies as a function of another wave known as the modulating wave.

Less broadly, it may be defined in radio practice as the impressing of intelligence on a carrier wave. Modulation may be of three main types: (1) *amplitude* modulation, in which the instantaneous carrier amplitude is a function of the modulating wave, (2) *frequency* modulation, which means that the carrier frequency is a function of the modulating wave and (3) *phase* modulation, in which the modulating wave varies the phase of the carrier wave.

MODULATOR. A device or circuit arrangement for producing a wave, some characteristic of which varies as a function of another (modulating) wave. See MODULATION.

MOLECULAR DEPRESSION CONSTANT, see FREEZING POINT.

MOLECULE. The smallest unit of an element or a compound that is capable of a separate existence. In this strict sense of the word, probably molecules exist in the gaseous state only, but the word is conveniently, though not very accurately, used to denote units of solid and liquid bodies that are more or less strongly combined with each other.

MOLYBDENUM (Mo). Atomic no. 42; atomic wt. 95·95. A soft, ductile, white metal, density 10·02 to 10·32; m.p. about 2500 deg. C. The principal use of molybdenum is to increase the hardness and strength of steel at high temperatures, and as a constituent of stainless and semi-stainless steels.

It has a very variable valency, 2, 3, 4, 5 or 6. The hexavalent compounds are the most important, e.g. molybdenum trioxide, MoO_3, from which may be prepared molybdic acid, H_2MoO_4, and a number of molybdates.

MONASTRAL BLUE. A pigment of recent invention. Of brilliant hue, it may be used in both water and oil mediums; in admixture with yellows it gives satisfactory greens and, with selected reds, purples.

MONEL METAL. A white nickel-copper alloy containing approximately two-thirds nickel and one-third copper. It is produced by the direct

smelting of a Canadian ore and not by mixing the constituent metals. Small amounts of iron, manganese, silicon and other elements are generally present. The alloy combines good strength, a property which it retains at elevated temperatures, with great resistance to corrosion. It may be fabricated by normal processes.

It is used for castings, such as steam-valve bodies, which have to operate under the combined action of stresses, high temperatures and possibly corrosive conditions. It is also used for pump impellers operating at normal temperatures but under severely corrosive conditions. Modifications of Monel, known as Monel H and Monel S, are produced by the addition of silicon in amounts of 2·75 and 3·75 per cent respectively. Castings made from these alloys may be heat treated, a considerable improvement in mechanical properties being obtained. Monel H, after heat treatment, has an ultimate stress of 33 to 40 tons per sq. in. and Monel S, 40 to 50 tons per sq. in. as compared with 23 to 33 tons per sq. in. for ordinary Monel.

In the wrought form Monel is used for laundry, chemical and textile equipment as well as for steam power-plant components such as pumps, valves, shafts, turbine blading etc. The tensile properties of ordinary Monel can be improved only by cold-working. A special variety known as K Monel, containing a small proportion of aluminium, may be heat-treated to give greatly increased strength and hardness.

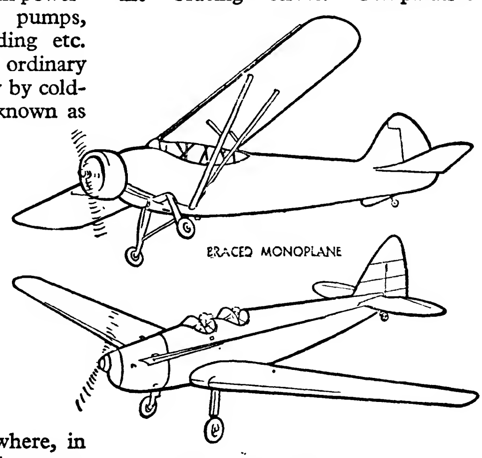
MONOBLOC. The casting, in one integral unit, of the cylinders of an engine, i.e. in the same cylinder block. This practice is now universally adopted in the construction of motor-car engines where, in addition to the cylinders, the upper half of the crankcase is cast as part of the cylinder block. Provision is made for main bearings, which carry the crankshaft, and to the casting are fitted the cylinder head, on top, and the sump, or oil container, below.

MONOCOQUE. A form of construction used in aero. engineering for fuselages etc., in which the skin carries all the load; it may be likened to a lobster's claw. True monocoque construction in which the skin is entirely unsupported is never found nowadays.

What is now called monocoque construction is really semi-monocoque in which the skin is supported by transverse frames and bulkheads and by longitudinal stringers. It is thus stabilized and a higher stress can be developed; at the same time the stringers carry some of the load.

MONOPLANE. An aeroplane with a single wing or plane. It is the most common type at the present day, because of its low drag, enabling a high performance to be obtained with a given expenditure of power.

Most modern monoplanes are of the cantilever type. A cantilever monoplane has a heavier wing structure than the corresponding braced type but the additional weight involved is considered worth while in view of the drag saved by eliminating the bracing struts. Comparative



BRACED MONOPLANE

CANTILEVER MONOPLANE

Of the two types of monoplane shown above, the cantilever design is more widely used in modern construction.

sketches of cantilever and braced monoplanes are shown in the illustration on the previous page.

MONOSPAR. The trade name for a patented form of aeroplane wing construction. Its main feature is that it has a single spar placed at about the deepest point in the wing section and braced with a special form of pyramidal torsion bracing. It was invented by Mr. Stieger, who claimed very light wing structure weights for his design. Several aeroplanes have been built with this type of wing construction.

MONOVALENT, see VALENCY.

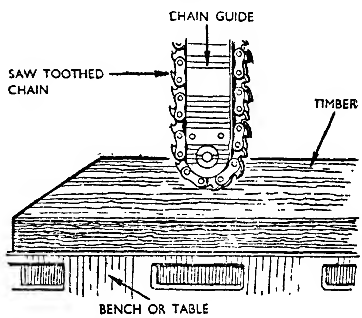
MORSE TAPER (Mech. Eng.). The standard forms of twist drill, whether for use in drilling machines or lathes, are provided with tapered shanks which fit into a correspondingly shaped socket in the machine spindle. The Morse taper is in general use for this purpose, so that any loose headstock, if of suitable dimensions, can receive the drill required.

If the tapered hole in the headstock is large and the drill is small, the external tapered shank of the drill can be "built up" by adding one or more similarly tapered sleeves till the right size is obtained. Thus any drills with shanks and sockets with the Morse taper can be used on any machine where the hole in the spindle also has a Morse taper.

Reamers, too, which are principally used in drilling machines, are thus also provided with shanks having Morse tapers. Extension sockets prolong the effective length and give a longer reach to a drill when deep holes have to be drilled. The standard Morse tapers are numbered from 0 to 7 inclusive; roughly they are ⅝ in. per ft. but the variation between sizes is as follows: No. 0, 0·6246 in. per ft.; No. 1, 0·5986; No. 2, 0·5994; No. 3, 0·6023; No. 4, 0·6233; No. 5, 0·6315; No. 6, 0·6256 and No. 7, 0·6240.

MORTAR. Material used in bedding and jointing bricks and stones in wall construction. Its function is to increase the strength of the work by adhesion and to provide a uniting cushion or bed between the units comprising the wall. *Lime mortar* is made from grey-stone lime or hydrated lime in the proportion of 3 parts sharp sand to one part lime. *Cement Mortar*, known as compo, consists of 4 or 5 parts sharp sand to one part Portland cement.

MORTISING MACHINE. These may be either hand- or machine-driven. The hand-driven type usually consists of a bed, or channel, to hold the work, a tool-holder suspended above it, and a balanced lever which brings the chisel down at the required point with a sharp blow. Although an improvement as regards speed on ordinary hand mortising, these machines are not to be compared with the chain mortiser, shown in the illustration. In this machine the actual cutting is done by a series of saw-like teeth, made in the form of a chain which revolves round a movable guide. As this guide is caused to descend on the workpiece, the saw teeth cut out the groove or slot. The machine is also provided with hollow chisels for narrow mortices. Inside the chisel is a twist-bit to remove the core.



Chain type of mortising machine.

MOTOR. All electric motors depend on one simple effect, namely, that a wire carrying a current is subjected to a force when it is in a magnetic field. The amount of the force is proportional to the strength of the field and the current in the conductor. Although the various types of motor differ in appearance and behaviour, the differences arise only because the

motors are designed to have different characteristics and to operate from a variety of supplies.

Direct-current motors are similar in construction to D.C. generators (q.v.). The commutator is again needed, this time to change the direction of the current in a particular conductor as it passes from the influence of one pole to that of the next, which has opposite magnetic polarity. There are the same commutation problems and interpoles are fitted for the same reasons as in the generator.

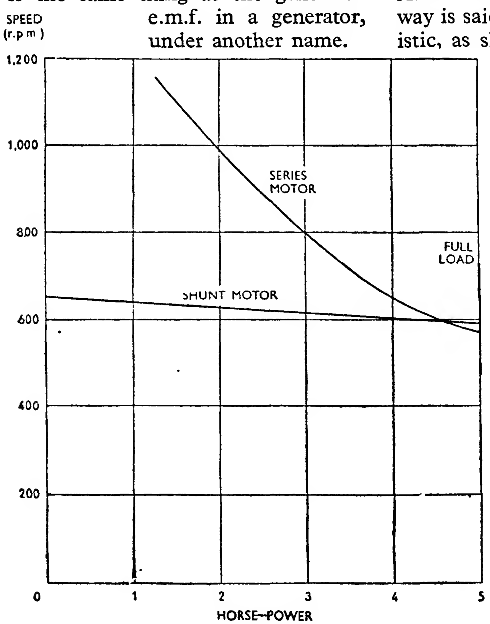
The nature of the field connexions affects the behaviour of a D.C. motor very considerably. When the field winding is in parallel with the armature, the machine is described as a shunt motor. The field current is substantially constant and so is the flux, except in so far as it is modified by armature reaction (q.v.).

A fundamental formula for a D.C. motor is $E=V-I_aR_a$, in which V is the supply voltage, I_a is the armature current and R_a the armature resistance. E is the back-e.m.f. which is the same thing as the generated e.m.f. in a generator, under another name.

It is evident that the conductors in a motor rotate in a magnetic field and must have an e.m.f. produced in them, just as in a generator.

The resistance of the armature is small, so that the product of I_aR_a is only a few per cent of V even at full load, when I_a is large, while at no-load when I_a is very small E and V are practically equal. It thus appears that most of the supply voltage V is used in overcoming back-e.m.f., that is to say, in doing mechanical work. The small proportion of V used to supply the voltage I_aR_a is wasted as heat in the form of armature copper loss.

The back-e.m.f., E, is determined, as in a generator, by speed and flux. It has already been shown that flux is nearly constant, and that E varies only a few per cent, say 5 to 10 per cent, between no load and full load. From this it follows that the speed varies similarly over the load range, that is to say, it drops steadily as the load is increased, the total fall being of the order of 7 per cent at full load. This speed characteristic is typical of a shunt machine, and any machine, A.C. or D.C., which behaves in this way is said to have a shunt characteristic, as shown in Fig. 1.



When the field is series-connected, so that the field winding carries the armature current, the characteristics will be entirely different.

At heavy loads the current is large and so is the flux, so that the speed needed to cause the generation of a back-e.m.f. approximately equal to the supply voltage, is low. At light loads, the current is small and so is the flux, so that the speed required to produce the same

Fig. 1. Speed/load curves of two 5 h.p. 200V. D.C. motors. Although both have nearly the same full-load speed, their characteristics are quite different.

back-e.m.f. (nearly) is very high. Indeed, it is so high that series motors cannot be run without load lest they destroy themselves by overspeeding. The typical series characteristic, then, is a high speed at no load, falling rapidly at first and then less rapidly, to a low value at full load, as shown in Fig. 1. The torque, which is approximately proportional to current, is high at low speeds. A machine behaving in this way is said to have a series characteristic. Such machines are particularly suited to traction work, cranes and similar duties.

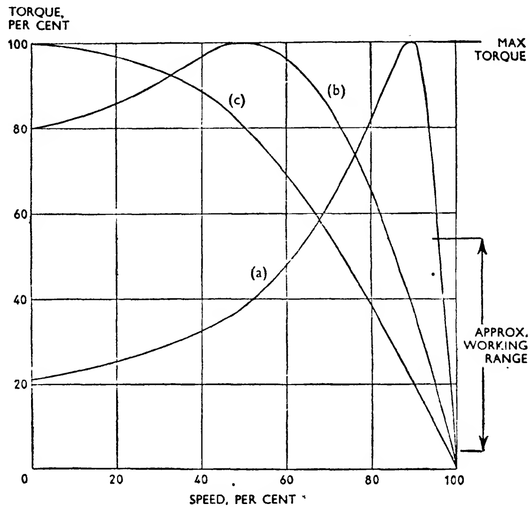


Fig. 2. Curves of torque and speed, as a percentage of synchronous speed, for a slip-ring induction motor. The normal characteristic is shown at (a), while (b) shows the effect of increasing the resistance five times. When the resistance is ten times that of (a), maximum torque occurs at starting (curve c). Note that the maximum torque is the same in each case and that torque is shown as zero for synchronous speed of the motor.

Compound-wound motors have both series and shunt windings which may be arranged to be cumulative, that is, to assist each other, or to be differential, that is, to oppose each other. The three types of field connexion are shown in the diagram under COMPOUND WINDING.

Speed control is effected either by varying the supply voltage by means of series resistances, or by varying the field current. The first method reduces the speed and is uneconomical unless the reduced voltage is specially generated, as in the Ward-Leonard system and in ships and vehicles using electrical transmission systems. Another disadvantage of series resistance is that it causes the speed to change rather widely as the load is altered.

The use of field control leads to speeds higher than normal and is commonly used for shunt motors. In the case of series motors part of the current is diverted from the field (see DIVERTER).

The most common type of A.C. motor is the induction motor. In its simplest form it has a poly-phase stator winding and a squirrel-cage rotor.

This arrangement results in a motor which is simple, cheap and robust and has a shunt characteristic. The main drawback is the low starting-torque and the poor power-factor (q.v.). Fig. 2(a) shows typical torque/speed curves for an induction motor.

Some improvement may be made by using a double-cage rotor, which contains two separate squirrel cages arranged to have different torque/speed characteristics, which, when combined, produce a characteristic of more desirable form.

The wound-rotor induction motor has usually a three-phase rotor winding brought out to three slip rings, to which variable resistances are connected. By varying these resistances, the maximum torque may

be made to occur at any speed, or at starting, as shown in Fig. 2. When the machine is running at normal speed with the resistance cut out, the slip rings may be short-circuited and the brushes lifted to reduce losses.

The synchronous motor is, in effect, an alternator (q.v.) run as a motor, and, like the alternator, it requires an exciter. It can run at one speed only (see SYNCHRONOUS SPEED) and if overloaded it merely stops. The great asset of such a motor is that its power-factor may be controlled by varying the excitation. In this way it may be used to compensate for the lagging power-factor of other motors, either unloaded, in which case it is known as a synchronous condenser, or it may do mechanical work as well.

Synchronous induction-motors are a mixture of the two types named. They run as synchronous motors until the load becomes too heavy and from then on they continue to run as induction motors.

Self-starting Motors

Apart from certain types to be mentioned later, single-phase motors are not inherently self-starting because the magnetic field produced by a single-phase supply is pulsating, while that produced by a poly-phase supply is rotating (see ROTATING MAGNETIC FIELD). These machines will run if they are started by some means, but to be self-starting they must be made to work two-phase, at any rate during the starting period. This is achieved by providing two windings carrying currents which differ in phase. The motor is then a split-phase motor and is named according to the method of phase-splitting employed, for example, capacitor motor. The starting winding may, or may not, be cut out of circuit when the motor is running.

Another device for making the motor self-starting, which is to be found only in small machines, is the shaded pole (q.v.).

A.C. commutator motors offer a variety of characteristics. They may behave like shunt or series machines; in some the power factor may be varied, while in others the speed is variable without undue loss.

In order to convert an induction motor into a variable-speed machine it is necessary to feed energy from the supply direct into the rotor circuit by some means other than the normal transformer action. To do this, a commutator and brushgear are needed to change the frequency of the supply to the slip frequency as energy is transferred to the rotor.

One type of motor has a normal induction-motor stator winding, but the rotor has a D.C. type of winding and a commutator with three brushes which are connected back to the supply by way of an induction regulator. The machine has shunt characteristics, but the speed may be varied by altering the voltage injected into the rotor, by means of the induction regulator. The usual range is from 50 per cent above synchronous speed to 50 per cent below it, but much wider ranges may be obtained.

Another version of the shunt-commutator motor has no separate regulator, but carries an additional winding connected to the commutator, and two sets of brushes. By moving the sets of brushes in opposite directions an increasing voltage is picked up and injected into the secondary winding, which in this case is on the stator. The winding, which is connected directly to the mains, is on the rotor and is fed through slip rings.

In this machine, speed control is obtained by separating the brushes. Control of power factor may be effected by moving the brushes as a whole.

A similar machine has a single set of brushes and by moving these the power-factor is controlled, but not the speed.

Series characteristics are obtained by using a series connexion by way of a transformer, which is needed because the commutator cannot deal with more than about 200V. Speed control may be obtained by moving the brushes. This is additional to the

variation of speed with load, associated with the series characteristic.

A modified D.C. series motor may be used on A.C. supplies because the directions of both field and armature currents reverse at the same time and there is no change in the direction of the torque. Universal motors having laminated magnetic circuits are used in small domestic and other appliances; they will run on either A.C. or D.C. supplies.

The repulsion motor is similar to the series motor but the armature brushes are connected together, so that energy is transferred to the rotor by transformer action. This motor has a series characteristic and a good starting torque.

A variation of the repulsion motor is the repulsion-start induction motor, which, as its name suggests, starts as a repulsion motor but is converted to an induction motor by short-circuiting the commutator when about 75 per cent of synchronous speed is reached. The motor then operates as a single-phase induction motor and has a shunt characteristic.

"MOTOR BOATING" (Radio). A descriptive term for a noise produced by unwanted feed-back in valve amplifiers. See INSTABILITY.

MOTOR CANNON or "engine cannon." Anglicized term for the *moteur canon*, a shell-firing gun used in conjunction with a liquid-cooled V engine, the propeller reduction gear being so arranged that the cannon, lying between cylinder banks, fired through the propeller boss. One advantage was that it was a convenient place to install the single cannon thought to be necessary a few years ago, at the same time eliminating the need for an interrupter gear (q.v.). It was developed by the Hispano-Suiza Company, who used an Oerlikon gun, and was fitted to some French fighters.

MOTOR CONVERTOR. A composite electrical machine consisting of a rotary convertor and an induction motor mounted on a common shaft, so connected that the rotor circuits of the induction motor are completed by way of the rotary-convertor armature.

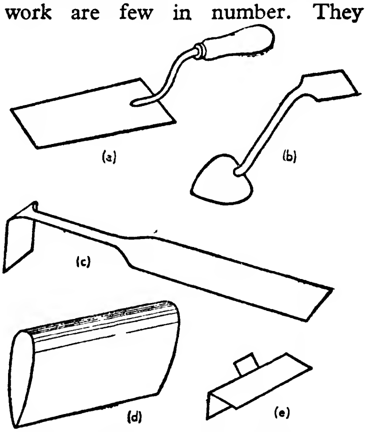
MOTOR GENERATOR. An electrical converting machine consisting usually of a motor driving a generator. The machines are separate, but mechanically coupled. As a rule, one is a D.C. machine and the other an A.C. machine.

MOTOR-VEHICLE LIGHTING, see LIGHTING FOR MOTOR VEHICLES.

MOULD DRESSINGS. Substances used to coat the faces of moulds to improve their refractory properties, to prevent penetration of the metal and to enable the sand to be stripped more readily from the casting. For dry-sand or loam work, blacking or graphite in the form of a thin paste may be used.

Talc or French chalk will give a better colour with non-ferrous work which is not to be sand-blasted. For green-sand work the dressing is usually applied dry, any excess being blown away by bellows.

MOULDER'S TOOLS. A moulder's personal tools for use in foundry work are few in number. They



Moulders' tools used in foundry work: (a) trowel, (b) heart and square, (c) cleaner, (d) wooden dabber and (e) edge sleeker. These are personal tools.

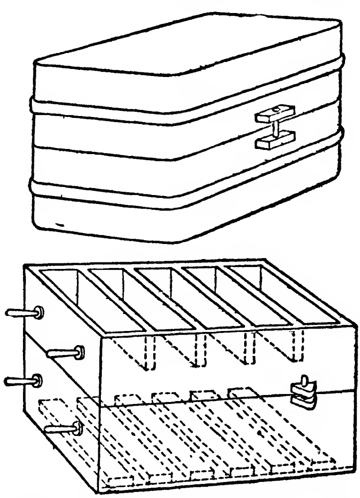
comprise a trowel, a heart and square, corner and edge sleekers, dabbers for forming core-irons and a cleaner. Representative tools are shown in the illustration. Other equipment

such as blacking brushes, rammers, shovels, sieves etc., generally form part of the shop equipment.

MOULDING, see DRY-SAND MOULDING, GREEN-SAND MOULDING, MACHINE MOULDING and MOULDING TECHNIQUE.

MOULDING BOXES. Any box in which a mould is made. The simplest type used in foundry work consists of two parts which fit together and are held in position by means of register pins. Neither part has a top or bottom, but flat horizontal bars may be fitted to the drag(q.v.), and similar bars set endwise in the cope as shown in the illustration. These bars are required to give additional support to the sand.

Small boxes are generally made of rolled steel and are without cross bars. Medium sizes are of cast-iron, the larger sizes being built up by bolting sections together at the corners. In all sizes, boxes of various depths are required. Boxes of the same size should be interchangeable, so that a deep drag may be mated with a shallow cope and vice versa, and so that additional sections may be introduced if more than one joint in the mould is considered necessary.



Two varieties of moulding box used in foundry work; above, rolled-steel box and, below, box of cast-iron.

In addition to any location pins, the various sections of a moulding box must be securely fastened together, generally by nuts and bolts, to resist the lifting effect of the metal on the cope. For small boxes, flat weights placed on top of the cope are generally sufficient.

For some classes of work special boxes may be used. Thus, for any large production of round castings, circular moulding boxes are employed. They are considerably lighter and less sand is required.

Small moulds are often made in snap flasks, that is, a moulding box hinged at one corner and fastened with a clasp at the other. By undoing the clasp the box may be removed from the mould before it is cast. In this way many moulds can be made in one box during the same day.

MOULDING MACHINES, see MACHINE MOULDING.

MOULDING SANDS. Sand is the most important of all the materials used in foundry work for moulding. Foundry sands consist of 85 to 90 per cent pure sand, the remainder being clay. Pure sand, though capable of being shaped when wet, has little or no strength, especially when dried. It is, however, permeable to gases, since many small voids are formed between the grains, and is very refractory. Clay possesses great plasticity when wet and is very strong when dried. It is, however, impermeable to gases.

In foundry sands, the properties of these two substances are combined. Many neutral moulding sands are available in this country, but in America they have to be made-up from the separate constituents.

Mixtures used for moulding do not, as a rule, consist entirely of new sand. Floor sand and other materials are added, the whole being thoroughly mixed and the correct quantity of water added before use.

Mixing should be very thorough, the object being to coat each grain of sand with a layer of moist clay, so that wherever one grain touches another a bond is formed. In this way

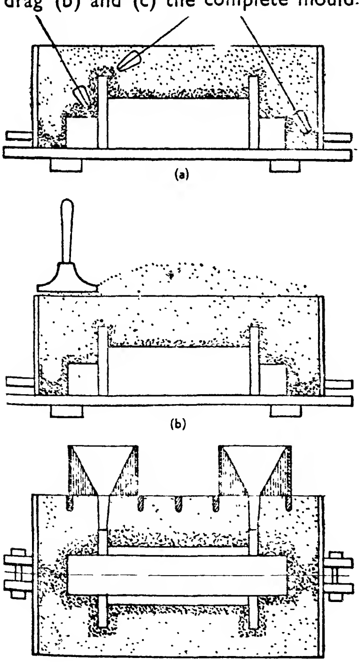
MIXTURES FOR GREEN-SAND MOULDING

Mixture Required For:	Light Work	General Work	Work Where Fine Finish Is Essential
Floor Sand	6	6	6
New „	1	3	3
Coal Dust	½	1	1
Blacking	—	—	1
Talc	—	—	⅓

MIXTURES FOR DRY-SAND MOULDING

Mixture Required For:	Light Work	Medium Work	Heavy Work
Floor Sand	6	6	6
New „	4	4½	5
Horse Manure	½	½	½

Below, diagram showing method of moulding a small pipe in green sand: consolidating sand round the pattern and edges of the box (a), flat-ramming the drag (b) and (c) the complete mould.


(a) (b) (c)

a minimum of clay and water is required to produce adequate strength and the sand remains very permeable. Mechanical mixers are now generally employed. The above tables give sand mixtures for various classes of work in green sand and dry sand.

The mixtures required for loam work are the same as those used for dry-sand moulding, additional water being added to give the necessary plasticity. Loam mortar may be made from floor sand milled with water and a little clay.

MOULDING TECHNIQUE. The operations involved in making a simple green-sand mould are best illustrated by an example, such as a small, flanged pipe. The half pattern is first placed on the turn-over board together with the bottom-half box, shown in diagram (a). Facing sand is riddled on top to a depth of 1½ in. and is pressed firmly in place round the pattern and the edges of the box, taking special care at the corners. The box is then filled with sand and rammed in the direction shown. Ramming is continued until the desired firmness is achieved with the rammer in a vertical position, taking care not to strike the pattern or to ram too much immediately over it;

this is a matter of experience and practice.

The drag is again heaped with sand and flat-rammed (diagram (b)), first round the edges and then working slowly towards the centre, any excess being scraped off with a straight-edge. The drag may then be turned over and the joint face sleeked with a trowel. The cope and second-half pattern are next placed in position and the cope rammed in exactly the same way as the drag. Runner and riser sticks may be included at this stage, or these passages may be cut afterwards.

When ramming is complete the cope is removed and placed pattern upwards on supports. The half patterns are rapped to loosen them from the sand and are then withdrawn. The core is next fitted, the ends being rubbed down until they seat accurately in the core prints. After any dirt has been cleaned out, and the faces dusted with talc or plumbago, the mould may be re-assembled, the drag and cope being bolted firmly together.

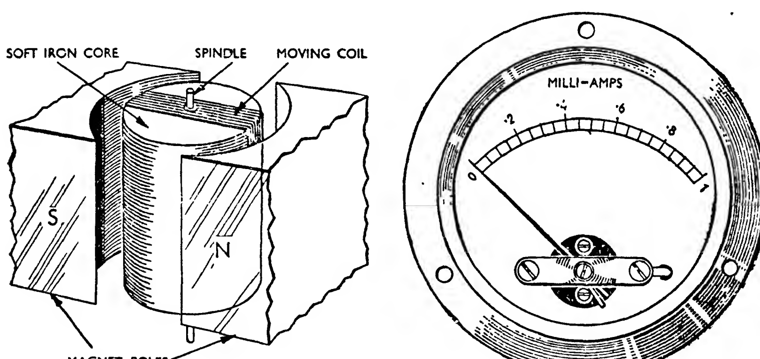
To complete the mould, runner and riser bushes are placed as shown at (c) in the illustration. To prevent the cope lifting under pressure of the metal, weights should be placed on the top, unless it is provided with crossbars, when they may be omitted.

MOUNTAIN ASH, see EUCALYPTUS.

MOVING-COIL INSTRUMENT. An electrical measuring instrument in which a coil carrying a current is acted upon and caused to move by a permanent magnet. The arrangement is shown in the diagram below, in which the position of the coil corresponds to about half deflection.

The same type of movement serves for a milliammeter as shown, ammeter, or voltmeter. The actual current in the moving coil is in all cases quite small, often 1 m.a. To make a voltmeter the current is limited by means of a large series-resistance, whereas for ammeters and milliammeters a shunt is provided internally or externally.

In the latter case the leads between the instrument and the shunt form part of the measuring circuit so that the readings may not be correct if the wrong leads are used. Moving-coil instruments work on D.C. only. They are characterized by the uniformity of the scale divisions.



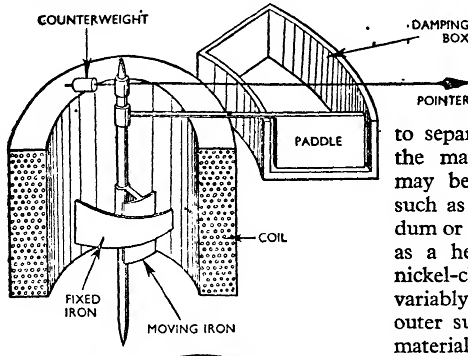
MOVING-COIL INSTRUMENT

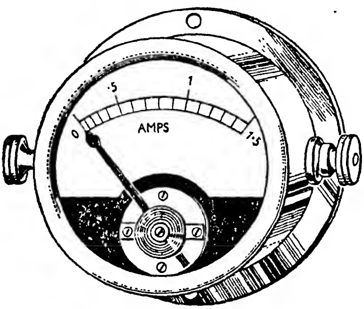
Milliammeter of the moving-coil type (right); the moving coil (left) is mounted in jewelled bearings and to it are attached the pointer, counter weights and two control springs, which also serve to lead the current to and from the coil. The soft-iron core, seen in the left-hand diagram, is held in position by a bridge piece.

MOVING-COIL LOUD-SPEAKER, see LOUDSPEAKER.

MOVING-COIL MICRO-PHONE, see MICROPHONE.

MOVING-IRON INSTRUMENT. An electrical measuring instrument in which the principle of action





Left, moving-iron instrument which uses air-damping to avoid undue oscillation of the pointer. Also shown is a moving-iron ammeter.

is based either upon the repulsion of two similarly magnetized pieces of soft iron, or upon the attraction of a single piece by a coil. The force depends upon current squared so that the instrument will operate on A.C. or D.C. and the scale is cramped at the lower end. In practice the moving irons are often shaped in such a way as to give a scale which is nearly uniform.

The construction of a double-iron type is shown above. The current required for full-scale deflection depends on the number of turns in the coil. The instrument may be used as a voltmeter by putting it in series with a high resistance.

MU. The twelfth letter of the Greek alphabet, written μ. It is the symbol used for magnetic permeability, amplification factor and other physical constants. The term "mu" is sometimes employed for mutual conductance but its use in this connexion is apt to be confusing.

MUFFLE. A continuous baffle or box made of some refractory material to separate from the source of heat the material being heat-treated. It may be made of ceramic material, such as carborundum, fireclay, alundum or fused silica, or of a metal such as a heat-resisting steel, iron or a nickel-chromium alloy. Heat is invariably applied by radiation on the outer surface of the muffle, and the material to be annealed or otherwise treated is placed within.

A muffle is used mainly for excluding products of combustion from contact with the metal being treated, when such products may be harmful, as in an enamelling furnace, to prevent specks on the finished product and also in certain bright annealing furnaces.

It also distributes heat more uniformly, especially if it is of high-conductivity material such as carborundum or a metallic alloy. It is less efficient thermally than direct heating or firing, as a higher temperature gradient is required in order to drive the heat through the muffle walls.

The term muffle is often erroneously used as a synonym for muffle furnace, since, several years ago, before the inception of modern methods of heating and firing, almost all the finer annealing operations were done in muffle furnaces.

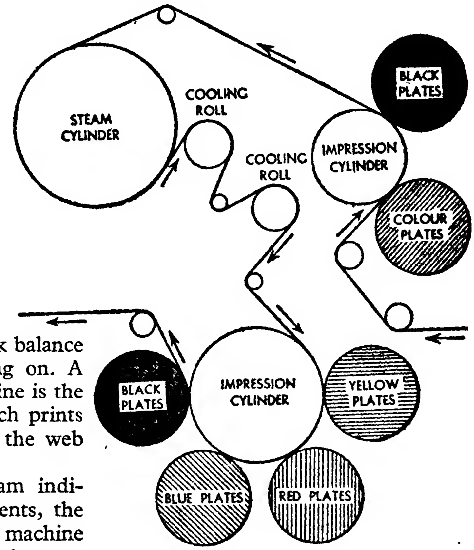
MULLION. A vertical member, or post, dividing a window into several lights. Mullions are shaped in section-like double posts or jambs. See WINDOWS.

MULLION WINDOWS, see WINDOWS.

MULTI-COLOUR MACHINES. The modern tendency in all printing processes is to reduce the number of printings when producing full-colour renderings, and at the same time to increase machine speeds. Printing two colours at the same time and on the same machine is a well-established practice.

Present demands require a com-

In multi-colour printing machines, the web travels over a steam drum and two small cooling rolls. Ink on first side, is therefore, dried before reaching second impression cylinder.



pleted print in full colour by passing the sheet or web through the machine once only. The great advantage of this is that the completed effect is visible at once and that, where necessary, modification of ink balance can be made before running on. A fine example of such a machine is the Cottrell magazine press which prints two colours on one side of the web and four on the other.

The accompanying diagram indicates the cylinder arrangements, the track of the paper through the machine and a method of drying the two colours on the first side of the web before printing the four colours on the opposite side. Questions of suitable paper, register, ink drying and ink superimposition make a highly complex problem, but work so produced reaches a surprisingly high standard and compares favourably with that done on two-colour machines. See WET-PRINTING PROCESS INKS.

MULTI-CYLINDER ENGINE. An internal-combustion engine having several cylinders, thus providing higher power-weight ratio. In single-cylinder four-stroke engines, only one power stroke takes place in every two revolutions of the crankshaft; in a six-cylinder engine, six power strokes in every two revolutions, while with eight- and twelve-cylinder engines, eight and twelve power strokes respectively are possible for every two revolutions.

It will, therefore, be clear that the more cylinders incorporated in an engine the shorter will be the interval between each power stroke and, consequently, the smoother will the engine run. Owing to cost of production, running and maintenance, however, the four-cylinder engine is a popular compromise for use in motor cars.

MULTI-PLATE CLUTCH, see CLUTCH.

MULTIPLE THREADS. The provision of more than one helix on a component which is subsequently to be given a rotary movement to operate a screw. A rod or shaft has frequently to receive a screw thread in which the pitch is very large compared with the diameter.

A single thread, if cut, would be large and deep and would considerably weaken the shaft. By arranging for two or more threads, cut parallel to one another, and all of the same pitch, as shown in Fig. 1, this reduction in

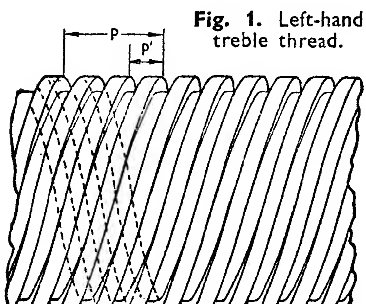
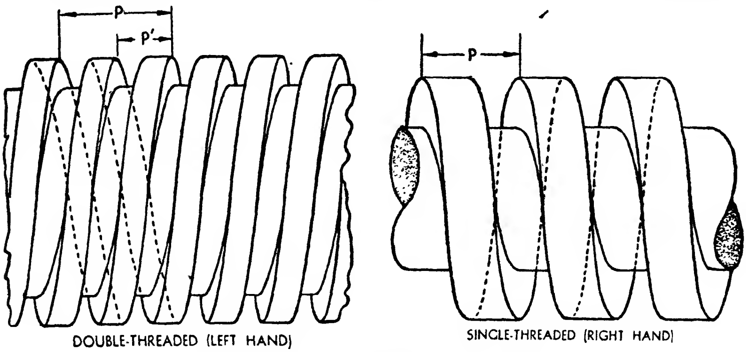


Fig. 1. Left-hand treble thread.



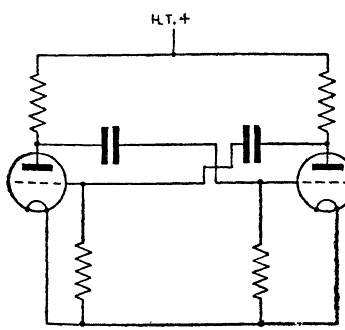
SINGLE AND DOUBLE THREADS

Fig. 2. Two varieties of thread. The double thread, shown left, has two parallel cuts, thus giving greater strength than the single thread on the right.

strength can be avoided. Another feature of multiple-threaded screws is that the total working surface of the screw, for a nut of given length, is greater than for the corresponding single-threaded screw.

The ratio of the pitch P (Fig. 2) to the number of threads is called the *divided* pitch (P^1). Threads may be either right- or left-handed, and examples of both kinds are shown. See LEFT-HAND THREAD.

MULTIVIBRATOR. A kind of *relaxation oscillator* in radio. In a usual form it is a two-stage resistance capacitance amplifier with its output connected to its input. Any potential change on, say, one control grid is amplified, undergoing a 360 deg. phase-change in the process and thus arrives back in phase with the original disturbance, providing exactly the right conditions for sustained oscillations.



Circuit diagram of the multivibrator; output may be taken from either anode.

MUMETAL. A nickel-iron alloy. It is characterized by the very low values of magnetizing force needed to produce normal flux-densities. See MAGNETIZATION CURVE.

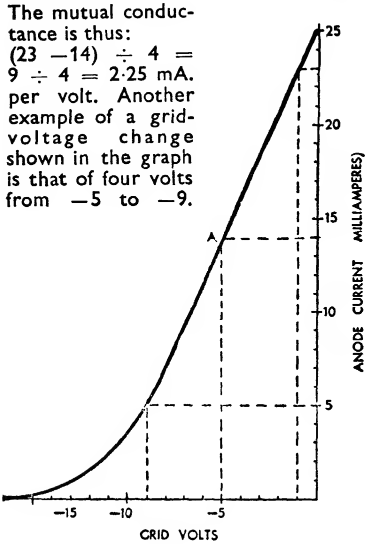
MUNTZ METAL. An alloy of the brass series, composed of about 60 per cent copper and 40 per cent zinc. It is a favourite metal for those portions of marine engines and auxiliaries which are not subjected to the corrosive effect of sea water. It is used for nuts and bolts as well as for castings.

Tensile tests have shown the strength of the alloy in tension to be as high as 40,000 lb. per sq. in., whilst extensometer readings give the elongation on the middle 2 in. of a tensile test piece as 25 per cent. The tensile strength can be further improved by suitable heat treatment; experiments have shown that a stress of 50,000 lb. per sq. in. is reached by subjecting cold-drawn bars to an annealing process, namely heating to 930 deg. F. for 48 hours. Care should be taken to see that the annealing temperature is not exceeded.

MUSH, see INTERFERENCE.

MUSH WINDING. A type of constant-pitch armature-winding for electrical machines which is often used for induction motors. The term is also applied to a bobbin

Graph explaining meaning of mutual conductance. A change of grid voltage of 4 volts, e.g. from -1 to -5, alters the anode current from 23mA. to 14 mA. The mutual conductance is thus: $(23 - 14) \div 4 = 9 \div 4 = 2{\cdot}25$ mA. per volt. Another example of a grid-voltage change shown in the graph is that of four volts from -5 to -9.



winding in which the turns are not separated into layers. See PITCH.

MUSTARD GAS. Dichloro-diethyl sulphide. One of the poison gases used in chemical warfare. The chemical constitution of the gas is $(ClCH_2.CH_2)_2S$. It is an oily liquid and has a smell like garlic; it is insoluble in water, soluble in many organic solvents. It is a vesicant, very poisonous and is decomposed by bleaching powder.

MUTING. A system of silencing the loudspeaker of a radio receiver while switching or tuning adjustments are being made, thus avoiding unpleasant or unnecessary noise. Automatic muting circuits are sometimes employed which cut off the loudspeaker during heavy static interference.

MUTUAL CONDUCTANCE. In a radio valve, the ratio of a small change in anode current to a small change of grid voltage, the anode voltage being kept constant. It is usually expressed in milliamps per volt and is a measure of the "goodness" of the valve. In the illustration the curve represents the relationship in a triode between anode current and grid volts for a fixed valve of anode voltage. See RADIO VALVE.

MUTUAL INDUCTANCE. Symbol M. The property of electrical circuits which causes a changing current in one to produce an e.m.f. in another which is magnetically linked with the first. The practical unit is the henry (q.v.) and the mutual inductance between two circuits is one henry if an e.m.f. of one volt is induced in one circuit when the current in the other changes at the rate of 1 amp. per second.

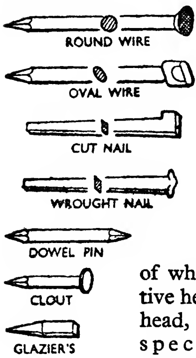
MYRTLE GREEN, see GREENS.

"MYSTIC EYE," see "MAGIC EYE."

NACELLE. A name originally applied to the body or fuselage of an aeroplane with a pusher engine, which necessitated the tail being carried on booms instead of being attached to the fuselage, modern examples being the Lockheed Lightning with tractor propellers and the jet-propelled De Havilland Vampire. It is also applied to the structure which houses wing engines, and to the engine cars of an airship.

NAILS. The smallest types of nail are called sprigs and tacks, and the largest, spikes. There is a big variety of metals, shapes and finishes, but the common kinds are distinguished as wrought, wire (oval or round), cut and clasp. They are named according to their uses, or to the shape of the point or head. The *oval wire* is used if the nail has to be punched below the surface of the wood, to enable the hole to be stopped for painting.

Round wire nails, owing to the flat head, give greater security, and they are less liable to bend. *Cut* nails are used chiefly for flooring, and *wrought* nails for heavy work, fencing etc. There are many special types, some



There is wide variety in the types of nail available, each being designed for a specific use. Shown here are five sorts of nail, a clout and a dowel pin.

of which have decorative heads, e.g. the rose head, and some have specially shaped shanks, as the screw nail, but these are not in common use.

Other common types are the *clout* nail for securing felt and sash cords; *dowel pins* for strengthening butt joints, instead of using dowels; *glazing* sprigs, for securing glass before puttying; *needle points* for very fine work, and panel pins, brads etc. Nails, at one time, were described as 3d. (three-penny) up to 60d. (sixty-penny). One explanation is that *d* stands for pound and that 10d. means that 1,000 nails weigh 10 lb. Another explanation is that 10d. means that the nails cost tenpence per hundred. For mass production, nailing machines are used. The nails are automatically fed into position from a hopper and driven into the wood by an automatic hammer.

NAPHTHA. A mixture of low-boiling hydrocarbons obtained in the distillation of coal tar, petroleum coal tar, or shale oil. It may consist chiefly of members of the paraffin series or of xylenes and other derivatives of benzine. Wood naphtha is obtained by the distillation of wood, and is chiefly methyl alcohol and acetone; it is used as a solvent and is mixed with alcohol to make methylated spirit (q.v.).

Naphtha is used in painting and decorating as a solvent and diluent for quick-drying and anti-fouling paints. Having great penetrative powers it may be used for protecting timbers from the spores of moulds, fungoids and from the ravages of insects. It also destroys germs in the early stages of their development.

NATURAL BED, see MASONRY.

NATURAL GAS. A gas, often found in the vicinity of oilfields, which may be collected and stored for use as a fuel. It usually contains about 70 per cent of methane, CH_4, the remainder being hydrogen, hydrocarbons and a little carbon dioxide, nitrogen and oxygen. See FUELS.

NECKING (Metallurgy). The local reduction in cross-section characteristics of a ductile specimen fractured in a tensile test, shown in the accompanying diagram. The specimen stretches under increasing load, but the cross-sectional area remains sensibly constant until a maximum load is reached, when necking takes place. The applied force now acts on a decreasing area and fracture occurs under a smaller load. This "breaking load" is not included in the results of a test.

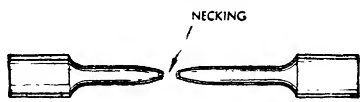


Diagram showing how necking takes place in fractured tensile test piece.

NEEDLE POINTS, see NAILS.

NEEDLE ROLLER BEARING, see BEARING.

NEGATIVE FEED-BACK. Transference or feeding-back in radio of some or all of the output of an amplifier to an earlier part of its circuit. If the phase of the voltage fed back is such that the sum of the original signal voltage and the feed-back voltage is less than the former alone, the feed-back is said to be negative. In this case, the overall amplification is reduced, but several important advantages result from its use. They are: (1) more uniform gain, (2) less harmonic distortion, (3) less phase distortion, (4) increased stability and (5) reduction of noise.

Negative feed may be classified as follows: (a) *voltage* feed-back, which is said to occur when the voltage fed back is directly proportional to the output voltage, (b) *current* feed-back,

which implies that the voltage fed back is proportional to the current in the output and (c) *bridge* feed-back, which is a combination of both voltage and current feed-back.

NEGATIVE G CARBURETTOR. A form of carburettor in which the float, acting on a needle valve to control the flow of fuel to the jets, is replaced by a diaphragm. The reason for this change is that the float is affected by negative gravitational forces such as when an aeroplane goes into a dive, or when flying upside down, thus upsetting the fuel supply, causing the engine to stop or run badly at critical moments in aerobatics. The substitution of the diaphragm eliminates these defects.

NEGATIVE RESISTANCE. The property possessed by any electrical device in which an increase of applied voltage results in a reduction of current. A screened grid valve has a negative-resistance portion in its anode volts/anode current characteristic.

NEON (Ne). Atomic no. 10; atomic wt. 20·18. One of the rare gases of the atmosphere. It is monatomic, i.e., the gas consists of an assembly of separate atoms; b.p. −233 deg. C.; m.p. −253 deg. C. It gives an orange-red light when an electric discharge passes through it at low pressure, and is used a great deal for illuminated signs.

NEON LAMP. An electrical discharge lamp containing the gas neon, which gives a pinky-red light. Such lamps are commonly used as pilot lamps or nightlights, owing to their low power consumption. See DISCHARGE TUBE.

NETWORK. A system of electric mains, distributors, feeders and other conductors, by means of which a supply of electricity is provided at a number of points. The term is also used in radio in connexion with filters. See DISTRIBUTOR, FEEDER and FILTER.

NETWORK CONSTANTS, see FILTER (Radio).

NEUTRAL POINT. A point in an electrical machine or transmission line to which all lines have equal voltages. For example, the star point of a star-connected transformer. It is often earthed in order to limit the potential between any live conductor and earth. See STAR POINT.

NEUTRON. When an element is bombarded with alpha particles, it often happens that particles are emitted which have a mass of approximately 1 (the mass of a hydrogen atom), but no electrical charge and no chemical activity. They contribute to the atomic weight of the element, but are not concerned in its valency or chemical properties. The difference between the atomic weights of isotopes is due to such neutrons, though whether they exist as such in the nucleus of an atom is not experimentally proved.

NEWS INK. Ink used for newsprint, consisting of carbon black dispersed in a mineral oil; sometimes a small amount of toner is added. Drying is entirely by absorption of ink by the paper. Because of the high printing speeds the ink is very free-flowing, and is often sprayed on to the inking system of the multiple-unit press. Water inks have found limited use, experimentally, for newspaper printing.

NEWSPRINT. A very cheap form of printing paper, which is manufactured mainly from a combination of mechanical wood-pulp and a lesser amount of sulphite wood-pulp. In Britain it is usually made from imported half-stuff board. Varying, but comparatively small, amounts of loading are used; the surface is calendered for improved rendering of half-tone blocks.

For newspaper printing the paper is cut to required width and wound on to reels as it comes off the paper-making machine; for jobbing work the paper is cut to various sizes and packed in reams or half reams.

NIBBLER. A type of shears for cutting sheet metal to template or scribed pattern. For forming operations it is sometimes necessary to impart a more intricate shape to the material than is possible on the guillotine (which cannot follow curves)

and such operations are readily performed on the nibbler. The machine usually incorporates cutters at the end of two jaws, forming a throat of suitable depth with provision for rigidly holding large sections.

NICHROME. The proprietary designation of an alloy of nickel and chromium; its heat-resisting and corrosion-resisting properties far transcend those of nickel alone, with the result that it is used for furnace parts, screens for use in sifting materials under the action of heat, and for various metallurgical processes involving direct exposure to temperatures of 1700 to 2200 deg. F.

Cast iron to which Nichrome has been added (when in the ladle) has valuable anti-corrosion and heat-resisting qualities as well as great resistance to wear; it is used for cylinder linings for internal-combustion engines, piston rings, cast-iron cams, valves for steam, gas or water, various types of bushings and light castings where brittleness must be avoided and where machinability and resistance to abrasion are of paramount importance.

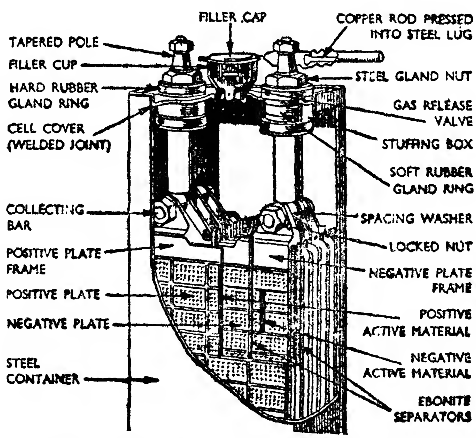
NICKEL (Ni). Atomic no. 28; atomic wt. 58·69. A ductile and malleable metal of whitish colour; it resists oxidation in dry air, although it slowly oxidizes in a moist atmosphere if acids are present. It is chiefly obtained from ores in Canada and is largely used for domestic articles. It is readily deposited by electrolytic means, so that nickel plating has become an important industry. The specific gravity of the pure metal is about 8·8, and its melting point is about 1450 deg. C. Nickel is one of the few magnetic metals, but this property vanishes at about 343 deg. C.

Nickel forms a vast and extremely important series of alloys with iron, steel and other metals. Nickel-chromium steel, in which the respective proportions of nickel and chromium are 1 to 5 per cent and 0·5 to 5 per cent, is used where high tensile-strength and resistance to shock are required.

Nickel steel, which usually contains 3 to 3½ per cent nickel, is very strong, very hard and highly ductile; it is used for armour plate as, with correct heat treatment, it fails to crack even when a projectile pierces it.

It is also used, in the construction of railways, for tracks and bridges etc. With the addition of vanadium (q.v.) it is a favoured alloy for automobile axles, crankshafts, machine-tool spindles etc.

NICKEL-IRON CELL. A secondary electric cell which uses an alkaline electrolyte, a nickel anode and iron and/or cadmium for the cathode. The construction of a typical cell is shown in the accompanying diagram. Nickel-iron cells have an e.m.f. of 1·4 volts when charged and may be discharged till the e.m.f. falls to about 1 volt, but there is no change in the specific gravity.



Cut-away view of a nickel-iron cell showing the main constructional features in detail.

NICKEL SILVER. An alloy which may be regarded as brass having a considerable proportion of the zinc replaced by nickel. A large number of different alloys are available. They

are whitish in colour and have excellent resistance to corrosion. The applications of these alloys are very varied, ranging from purely decorative castings to such heavy-duty work as high-pressure steam fittings.

The composition required by the British Admiralty Electrical Specification for castings is: nickel 18 to 22 per cent, zinc 20 to 22 per cent and the remainder copper. As with other nickel alloys, sulphur picked up during melting may cause weakness in the metal. The remedy is to melt under oxidizing conditions so that the sulphur is burnt instead of being absorbed, and finally to deoxidize with magnesium or manganese.

NIGHT EFFECT. In radio direction-finding apparatus, an error due to the polarization of the sky-wave, or indirect ray.

NITON, see RADON.

NITRIDES, see NITRIDING.

NITRIDING. Method of surface hardening applied to certain special steels. A typical nitriding steel contains 0·2 to 0·5 per cent carbon, 1·1 per cent aluminium, 0·2 per cent molybdenum.

Before nitriding, the steel is heat-treated (i.e. oil-quenched and tempered) to obtain the required properties in the core. A stress-relieving treatment consisting of 5 hours at 540 deg. C, followed by gradual cooling, should be given before finish-machining. To nitride, the parts are heated for 40 to 90 hours at 500 deg. C. in a sealed container through which ammonia gas (NH_3) is circulating. The ammonia is dissociated into nitrogen and hydrogen, the nitrogen combining with the surface metal to form compounds called *nitrides*, which have a powerful hardening effect. A slight increase in diameter of about 0·001 in. takes place, and this should be allowed for in finish-machining.

A core strength of 75 to 85 tons per sq. in. and an intensely hard case (Vickers Pyramid Numeral 1050 to 1100) may be obtained in a nitriding steel of suitable composition. Where a less hard, but tougher, case is adequate, an aluminium-free steel with 3 per cent chromium and a little molybdenum may be used.

Nitriding gives a harder case than ordinary case-hardening (carburizing), and distortion is eliminated, since no quenching is necessary after hardening. The process is admirably suited to innumerable parts, including crankshafts, gears and press tools. Nitrided steel tools for pressing and drawing combine high resistance to crushing with a surface remarkably free from fouling tendencies.

NITROBENZENE, see BENZENE.

NITROGEN (N). Atomic no. 7; atomic wt. 14·008. A colourless gas forming about 75 per cent by weight of the atmosphere. It can be condensed to a colourless liquid, and by further cooling, to a white solid, m.p. -210 deg. C.; b.p. -196 deg. C. It is obtained on a large scale by the distillation of liquid air. It combines with hydrogen in the presence of a catalyst, e.g., iron or molybdenum, forming ammonia, NH_3.

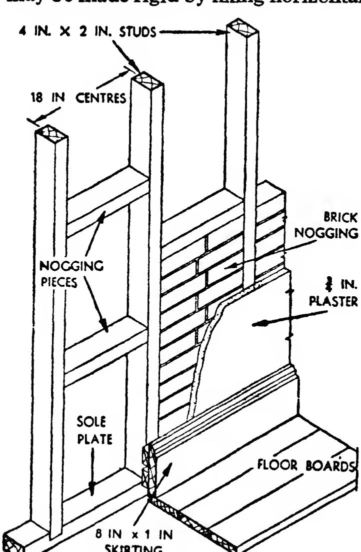
This process is now used on a very large scale for the manufacture of the important fertilizer, ammonium sulphate, $(NH_4)_2SO_4$. Nitrogen is pentavalent, and forms many compounds with oxygen, nitrous oxide, N_2O; nitric oxide, NO; nitrogen dioxide, NO_2; nitrogen trioxide, N_2O_3, and nitrogen pentoxide, N_2O_5. Nitrous oxide was formerly known as "laughing gas"; it is sold in steel cylinders as a mild anæsthetic for minor operations.

Nitrogen pentoxide combines with water to form nitric acid, HNO_3, a colourless liquid, used on a large scale in the manufacture of fertilizers, such as nitro-chalk, a mixture of calcium carbonate and ammonium nitrate, also in the manufacture of explosives such as nitro-glycerine, $C_3H_5(NO_3)_3$, an oily liquid which, when mixed with the mineral kieselguhr, is known as dynamite.

Gelignite is another explosive containing a high percentage of nitroglycerine. Cordite is a variable mixture of 30 or more parts of nitroglycerine, 65 or less parts of gun-

cotton, about 6 parts of acetone, and a little vaseline. Gun-cotton is a cellulose nitrate, approximately $C_{12}H_{14}O_4(NO_3)_6$, obtained by treating cotton with nitric acid. Another important explosive is trinitrotoluene (TNT), $C_7H_5O_6N_3$. Other well-known nitrates include sodium nitrate, $NaNO_2$, otherwise called Chile saltpetre, a well-known fertilizer; silver nitrate, $AgNO_3$, is the most important silver compound, used as a caustic and a disinfectant, and in photography. Saltpetre is potassium nitrate, KNO_3. Nitrobenzene, $C_6H_5NO_2$, is a colourless liquid obtained by treating benzene with a mixture of nitric and sulphuric acids; it is used in perfumery and in the manufacture of aniline and many dyestuffs.

NOGGING. Bricks or precast partition slabs, often used, in the construction of walls, to fill the spaces between partitions. Wood-stud partition framework consists of a sill-piece and head-piece into which are housed the vertical studs, which are placed about 16in. apart. These studs may be made rigid by fixing horizontal pieces of wood, termed *nogging pieces*, between the studs at intervals throughout the wall area.



Method of using brick nogging to fill in spaces in a partition wall.

NOGGING PIECES, see NOGGING.

NOISE (Radio). Noise in radio receivers may be divided broadly into two classes. First, that arising within the receiver itself and, secondly, that picked up by the aerial or other parts of the apparatus. The former may be partly inherent and partly due to imperfections of components, faulty connexions, and so on. Inherent noise is a vast and complicated subject and is attributable to many effects of which the following are the chief:

Electron flow from cathode to anode is not uniform, electrons tending to traverse the space in groups or clusters (shot effect); electrons tend also to have random movements in other components. These irregularities are of little importance except in the earliest stages of an amplifier, when the voltages they produce are amplified and heard as background noise which may be recognized as a sound not unlike hail falling upon a thin wood roof. The ratio of signal strength to this background noise sets the ultimate limit to sensitivity of amplifiers. The cure of noises due to faults is fairly obvious and requires the careful checking of components, soldered joints, sockets and connexions.

Noise originating outside the receiver is often more appropriately termed interference (q.v.). It may or may not be possible completely to eliminate this trouble, but efficient aerials with screened down-leads, adequately screened components, efficient earth connexions and certain other precautions all contribute towards reducing such interference to a minimum.

NO-LAG MOTOR. An electric commutator motor having a shunt characteristic. The power factor is normally leading but may be varied by shifting the brushes. See MOTOR.

NO-LIFT ANGLE, see AEROFOIL SECTION.

NOMAG. A manganese-steel alloy which is practically non-magnetic.

NON-FERROUS ALLOY. An alloy whose properties are due primarily to the non-ferrous metals present, although it may contain iron in amounts up to 50 per cent. Non-ferrous alloys are used in both the cast and wrought conditions, the following being the most common: copper-zinc (brasses); copper-tin (bronzes); tin-base; lead-base; copper-nickel; copper-nickel-zinc (nickel silvers); copper-manganese; aluminium-base; magnesium-base; resistance, heat-resisting and cutting-tool alloys.

The brasses may range from over 90 per cent to just under 50 per cent copper. Typical brasses are Muntz metal (60 per cent copper, 40 per cent zinc), deep-drawing brass (70 per cent copper, 30 per cent zinc) and battery-copper (94 per cent copper, 6 per cent zinc). Special brasses contain small additions of manganese, iron etc. to improve the mechanical properties. Aluminium bronzes (containing 3 to 10 per cent aluminium) and silicon-bronzes (1 to 4 per cent silicon) are almost as well known as the brasses and tin bronzes. Tin-base alloys include pewter, babbitt and other white metals. Lead-base alloys include accumulator, linotype, shot-lead and Terne metal. Nickel-base alloys containing copper are used where high strength combined with resistance to corrosion is required. Copper-manganese alloys are used for electrical work and aluminium and magnesium alloys where high strength combined with lightness is required. Resistance and heat-resisting alloys consist mainly of nickel with chromium and iron. Cutting-tool alloys include the ferrous alloys such as high-speed tungsten and other alloy steels, and the non-ferrous alloys such as tungsten-carbide and boron-carbide.

NON-LINEAR DISTORTION, see DISTORTION.

NON-METALLIC INCLUSION (Metallurgy). A particle of non-metallic material present in a metal or alloy, visible as a distinct phase. The definition excludes non-metallic phases forming part of the particular alloy system. Thus, particles of iron carbide present in steel, though non-metallic, are not regarded as inclusions because steel is an alloy of iron and carbon.

Non-metallic inclusions may arise in several different ways. Thus, in pouring liquid metal into a mould, a small quantity of slag may become entangled with the liquid metal and fail to rise to the surface before the metal has solidified. Non-metallic inclusions may also be produced as a reaction product in an alloy manufacturing process. For example, in the manufacture of steel it is impossible to remove all the sulphur present, some 0·02 to 0·05 per cent remaining in the liquid metal. On solidification, and in the absence of any manganese, the sulphur would collect at the grain boundaries in the form of brittle films of iron sulphide, so reducing both the strength and ductility of the resulting steel.

To avoid this, about 0·5 to 1·0 per cent of manganese is added to the melt. The sulphur reacts preferentially with the manganese to form small more-or-less rounded particles of manganese sulphide in the solid steel, in which form it has little or no effect on the mechanical quality of the steel. Indeed, by deliberately permitting 0·2 to 0·3 per cent of sulphur to remain, so that a correspondingly larger amount of manganese sulphide is formed, the machinability of the steel may be greatly increased. Care is necessary to ensure that the particles of manganese sulphide formed are small and evenly distributed, or the mechanical quality of the steel will be greatly reduced.

Non-metallic inclusions may also be introduced in hot-working operations, particles of scale being forced into the metal, especially if a lap or fold is produced in the surface. On hot-rolling, inclusions originally present in a metal or alloy as particles of rounded form become elongated in the direction of rolling. This accounts for the fibrous nature of wrought-iron, which frequently contains a considerable quantity of slag.

In cold-working processes, large inclusions may set up cracks or tears in the material being worked.

NORMAL ASPIRATION. An internal combustion engine is said to be normally aspirated when it depends entirely on the atmospheric pressure to introduce the combustible charge into its cylinders.

Thus, as the pressure and the density of the air fall with increasing altitude, the power of a normally aspirated engine, which depends on the weight of air drawn in, is greatest at sea level, and decreases with increase in altitude.

NORMAL FORCE. In aircraft engineering, the component of the air reaction which acts at right-angles to the chord line of an aerofoil, or, more precisely, the zero lift line.

NORMAL FORCE CO-EFFICIENT. A non-dimensional co-efficient which relates the normal force to the wing area, the speed of the aeroplane and the atmospheric density, in a manner similar to that in which the lift coefficient defines the variation of lift.

NORMALIZING. A special form of annealing (q.v.), or heat treatment, in which the article is allowed to cool freely in still air from above the critical temperature (q.v.). In steel, a finer structure with better mechanical properties is obtained by normalizing than is possible with annealing. Its use is, however, confined to relatively small articles of regular shape, as large irregular-shaped articles are liable to develop internal stresses if subjected to this process. In such cases full annealing is, therefore, preferable.

The purpose of normalizing is to refine the grain structure and produce a uniform condition free from stress, so that further heat treatments can be carried out; it is thus particularly useful for forgings which have afterwards to undergo additional heat-treatment processes. The machinability is also affected, but it is the composition of the steel which ultimately decides whether, after normalizing, it will be soft enough for machining operations to be performed. It frequently happens that normalizing is all that is needed to put low-carbon steels into their best condition for machining and to secure minimum distortion during carburizing or case-hardening (q.v.). For medium and high-carbon steels, however, the normalizing and annealing processes are often combined. In the manufacture of components of minor importance, normalizing is often omitted altogether; or an annealing process may be adopted merely to render the steel easier to machine.

NORMAL PORES, see POROSITY.

NOSE BALANCE, see BALANCED CONTROL.

NOSE-SLOT COWLING. A form of radial air-cooled engine cowling, investigated in the U.S.A., which differs from the general form of cowling in that the cooling air admitted through the front of the cowling passes through the engine and is then brought forward again. It is emitted from a slot on the nose of the cowling where there is a region of low pressure, instead of through a slot a little distance behind the engine. The advantages claimed for this arrangement include better cooling under low-speed conditions, i.e. during take-off and climb.

Another variation is that in which the air is collected by intakes in the leading edge of the wing and is then passed through the engine from back to front and exhausted through the nose slot as before.

NOSEWHEEL, see UNDERCARRIAGE.

NOTCHED-BAR TESTING. A form of test in which a notched metal bar is broken, generally by the

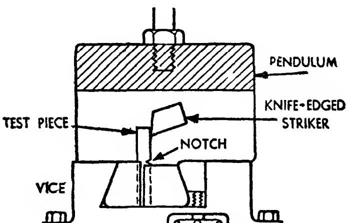


Fig. 1. Pendulum of an Izod notched-bar test machine at point of impact.

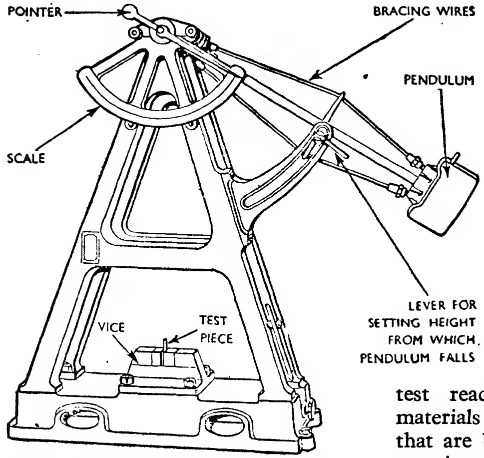


Fig. 2. Work done by the pendulum of an Izod test machine in breaking the test-piece is shown on the scale.

impact of a heavy pendulum, and the energy used in breaking the bar recorded in foot-pounds. The Izod machine, as shown in Fig. 2, is commonly employed. The test-piece, which may be cylindrical or square, is supported in a massive anvil, and is struck by a heavy pendulum released from a standard height. The notch in the test-piece must always face the pendulum.

A typical test-piece is shown in Fig. 1. The pendulum, after striking the test-piece, swings on to a height depending on the work done in breaking the test-piece. This value is indicated on the scale by a slave pointer carried forward by the pendulum.

As a rule, the test-piece fails by cracking, which is initiated by the notch, but very tough materials may bend without cracking.

The test is often described as measuring the resistance of a material to impact. This is true only in a limited sense. Thus, a lathe tool used in turning an irregular object may receive a heavy blow each time the tool makes contact with the work, yet the Izod value of the tool may be very low. The test is of value only for relatively ductile materials which, under suitable conditions, may fail in a brittle manner.

This is particularly true of threaded parts such as eyebolts, or parts with a sudden change of section, especially those of relatively small size. Such parts are often subjected to an overload in service, usually produced by impact or shock. The Izod test readily distinguishes between materials that are tough and those that are brittle for such duties. The test is applied very largely to bar steel, and only rarely to other materials. Cast-steel and cast-Monel are, however, sometimes tested in this way.

NOTCH EFFECT. The intensification of stress produced at a notch, or other sudden change of section, in a material under load. For example, a square bar under a tensile load will be stressed uniformly across its section. The intensity of stress may be conveniently indicated by drawing

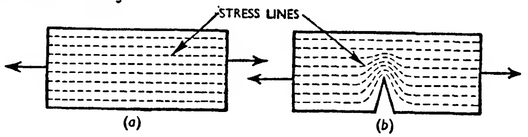


Diagram showing stress lines produced in unnotched bar (a) and notched bar (b) under tensile stress. Note stress concentration round notch.

equidistant parallel lines, as shown at (a) in the accompanying illustration, the number of lines per inch of section indicating the intensity of the stress.

Cutting a sharp notch on one side of the bar will cause the lines of stress to crowd-in near the root of the notch, indicating a stress concentration in this region, as shown at (b). The intensity of stress produced at the root of the notch may be more than

ten times the average stress over the section. A similar effect is produced by any sudden change of section.

Notch effect is responsible for the failure of many machine parts in service. To reduce the possibility of failure, changes of section should be made as gradual as possible, for example, by providing adequate radii at sharp corners, shoulders on shafts, and so on.

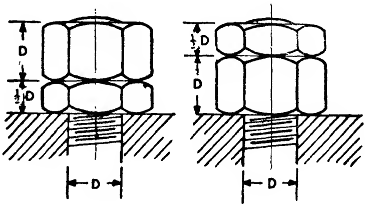
NOTCH JOINTS, see JOINTS.

NOZZLE. A fine tube or outlet through which a fluid is made to pass under pressure to induce a fine spray. In metallurgy, the jet at the extremity of a welding blowpipe (q.v.) through which the oxy-acetylene gas mixture issues. The size of the nozzle orifice, in conjunction with the gas pressures, determines the size or "power" of the flame, which must be varied to suit the thickness and class of metal being welded. Blowpipes are therefore usually provided with a range of nozzles to suit different thicknesses of metal.

Internal-combustion engines operated by compression-ignition have special nozzles, or atomizers, incorporated in the injectors which are fitted in the cylinder head. Through these injectors, the fuel is sprayed into the combustion chambers. There are several designs of nozzle in general use, of which the single-hole, multi-hole and pintle types are examples (see COMPRESSION-IGNITION ENGINE). By use of the differently shaped nozzles the form of the fuel spray may be altered, the pintle design being more often used in engines incorporating the swirl-type of combustion chamber.

The jet orifice of a reaction-propulsion engine is sometimes referred to as a nozzle. Its shape is based on the principle of the venturi tube, the purpose being to accelerate the rearward ejection of gases, so imparting an increased forward thrust to the engine.

NUTS. One of the two principal parts of the commonest type of fastening for metal components, the other being the bolt (screw-threaded).



Two methods of using a lock nut, that on the right being the more common.

The normal proportions of nuts are:

(1) Hexagonal nut: Thickness of nut = diameter of screw = D. Width across flats = $1\frac{1}{2}D+\frac{1}{8}$ in. Width across corners = width across flats × 1·155.

(2) Square nut: Thickness of nut = diameter of screw = D. Width across flats = $1\frac{1}{2}D+\frac{1}{8}$ in. Width across corners = width across flats × 1·414.

(3) Circular nuts: Thickness = diameter of screw = D. Diameter (external), from $1\frac{1}{2}D + \frac{1}{8}$ in. to $1\frac{3}{4}D$.

Lock nuts are used to prevent a nut from working loose; the screwed bolt or stud is lengthened so as to accommodate another nut screwed up tight against the first nut. The second nut is the lock nut; it must be screwed so tightly against the first nut that the two are wedged firmly together. As theoretically the *outer* nut bears the load or stress on the bolt, it is considered better practice by some to make the outer or lock nut the full thickness D and to make the first nut much thinner, say ½D. In practice, however, the thinner nut is very often made to do duty as the lock nut because the spanners in general use are too thick to get at the thinner nut if it is on the inside. This is shown in the illustration.

Other devices for locking nuts may involve the use of (a) set screws or grub screws, usually biting against grooved collars made integral with the nut; (b) various forms of metal holding-plates which fit the corners of the nut and are screwed rigidly to the surface against which the nut is bearing; (c) various forms of castellated nuts, involving the use of split pins or cotters to secure the nut.

OAK. A hardwood with over 300 varieties, employed where strength, durability and appearance are required. English oak is the best, but is difficult to work owing to its hardness and irregular grain.

American and European woods, therefore, are in more general use because only selected wood is imported, and more attention is given to the conversion for silver grain. American oaks are divided into red and white; the former is softer and lighter than other species, and is easily wrought; the latter is somewhat like English oak, but little is exported. European oak is generally of the same species as English. There are several English species, some of little importance, while other species are imported from all over the world. See TIMBER.

OCCLUSION. The property which some substances possess of retaining gases. The metal palladium, for instance, has a remarkable power of absorbing hydrogen. A few other substances have a similar power to a lesser extent. Palladium can occlude 900 times its volume of hydrogen, and it is possible that a compound PdH_2 is formed or that an interstitial compound is formed. Heating drives off some of the hydrogen; the occluded hydrogen is chemically very active.

OCHRES. Naturally occurring pigments varying in colour from a brownish to a reddish hue of yellow, and consisting of an earthy base stained with hydrated ferric oxide (oxide of iron). They are very permanent, work well with all mediums but vary considerably in both opacity and staining strength.

OCTANE NUMBER. An expression of a motor fuel's resistance to detonation in relation to an arbitrary standard. It is defined as the percentage by volume of iso-octane in a mixture of iso-octane and normal heptane, which, when tested under certain standard conditions in a special engine, has the same knock or anti-detonation properties as the fuel under examination. The higher the octane number, i.e. the greater the percentage of iso-octane required to match the properties of the fuel under test, the greater is its anti-detonation value.

Fuels are in use today, particularly in aircraft engines, with an octane number of 100, but new ones have been developed in the laboratory which have better anti-detonation properties than the standard set by iso-octane. See OCTANES.

OCTANES. Hydrocarbons of the paraffin series with the formula C_8H_{18}; there are many octanes, of which one, iso-octane, has valuable anti-knock properties. The quality of motor or aviation spirit was formerly judged by testing it against mixtures of iso-octane and heptane; the octane number (q.v.) was the percentage of octane in a mixture with equal performance. The octane rating is now obtained by comparing the performance of the spirit with that of other standard mixtures.

OCTODE. A radio valve having eight electrodes, that is, six grids as well as a cathode and anode. Its chief application is in a superheterodyne receiver as a frequency changer.

ODD-SIDE. In moulding and foundry work, a device often used to replace a turn-over board. It consists of a false cope on or in which the pattern is placed. The drag is then rammed-up using the odd-side as if it were a turn-over board. This device is especially useful for moulds requiring irregular joints.

A cope rammed with floor sand and strickled flat may be used for flat joints. If the joint is irregular, and a number of moulds are required, a semi-permanent odd-side is often used. This may be made from dry-sand, the surfaces being hardened by coating with tar and stoving. Alter-

natively, plaster of Paris may be employed.

In making a dry-sand odd-side, the pattern is rammed-up in the drag, turned over, and the joint face carefully shaped with a trowel. After covering with parting sand, the cope is placed on top and rammed in the usual way. After drying, coating the surfaces with tar and stoving again to harden, the odd-side is ready for use. If it has been made properly it should serve for making many moulds.

OERSTED. A unit of magnetizing force (q.v.). A unit pole experiences a force of 1 dyne when the magnetizing force is 1 oersted.

OFFSET DEEP, see DEEP ETCH.

OFFSET PRINTING. For practical purposes this is an exclusively lithographic process. The printing forme may be made by any of the various lithographic or planographic methods, but the image must appear on the forme in the way it is required to be printed, and not reversed. The print is first taken on a rubber blanket and transferred to the paper or other material to be printed.

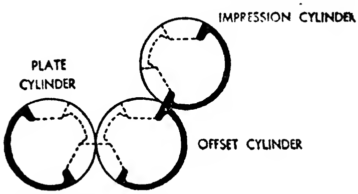
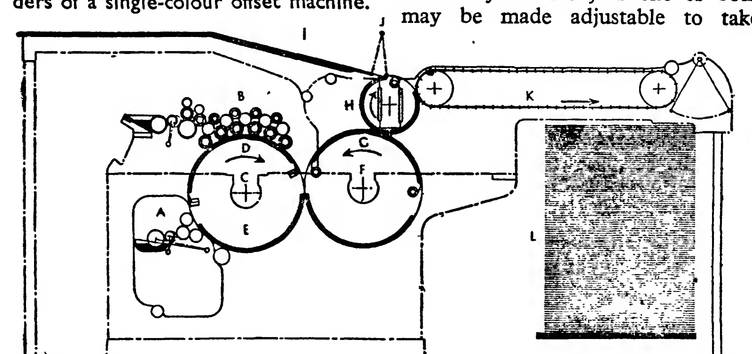


Fig. 1 (above). Diagram showing cylinders of a single-colour offset machine.



LITHOGRAPHIC OFFSET MACHINE

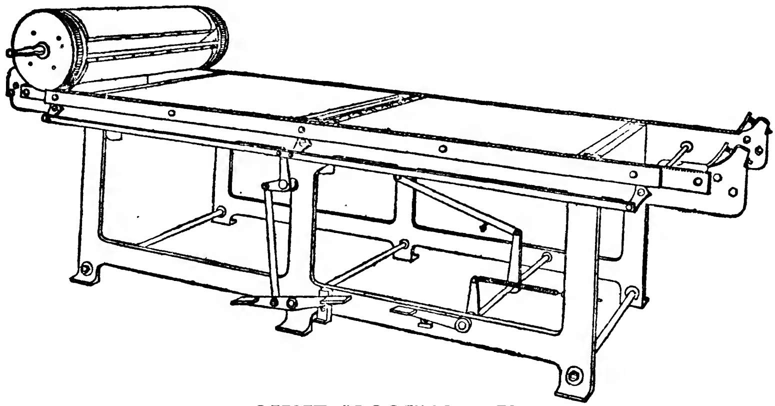
Fig. 2. Main components shown are: A damping system; B inking system; C plate cylinder; D plate; E ink slab; F blanket cylinder; G blanket; H impression cylinder; I feed board; J swing feed; K chain-delivery grippers and L pile delivery.

General practice is to stretch the offset blanket round a special offset cylinder as indicated in Fig. 1. Details of the pile delivery of a machine of contrasting type are shown at Fig. 2.

Compared with direct printing, the main advantages of the offset method are that practically any paper which is manufactured in sheet form can be printed, from heavy metal plate to tissue paper, while hard or rough paper-surfaces are particularly well dealt with. Reproduction of fine detail is a feature, as indicated by the 400-line screen of the aquatone (q.v.) process, while high speeds and long runs are obtained through the reduction of pressure and friction.

OFFSET PROOFING PRESS. A simple machine, used in the printing trade, and designed primarily to produce offset proofs more cheaply and speedily than by the offset printing machine. It consists essentially of two steel beds, one behind the other and in the same plane; both beds may be fixed, or one or both may be made adjustable to take stones, blocks, or other printing surfaces. The plate is fastened on one bed while the other accommodates the material to be printed on.

The offset blanket is stretched



OFFSET PROOFING PRESS

In an offset proofing press, two steel beds are used, one of which takes the plate, while the other carries the material to be printed on. Round the cylinder, shown on the left, is stretched the offset blanket which takes an impression from the forme or plate on the bed. Various methods of inking are used.

round a cylinder which rolls over the two surfaces and is kept in alignment by gears, while contact or otherwise by the blanket and printing surfaces is controlled by the eccentric bushes in which the cylinder spindle is set, or by other mechanical means. The plate is inked by hand and the cylinder in the lowered position is rolled over the plate, making one revolution and taking an impression on the rubber blanket. The sheet to be printed is placed in position on the second bed and a second revolution of the cylinder transfers the impression to the sheet. Provision is made for registering colours, and during the printing operation the sheet is held firmly in grippers.

This type of press is made by all lithographic machine makers, their individual ideas sometimes being incorporated. Some presses of this type are extremely simple, while others include mechanical damping and inking apparatus together with a power unit for operating the cylinder, so that short runs can readily be printed. Such a machine is useful for printing glass, wood and similar sheet material which is unsuitable for passing round or between machine cylinders in the usual way. This type of press may also be used for making duplicate printing plates by using retransfer ink and substituting a counter-etched litho plate for the printing paper. See OFFSET PRINTING.

OHM. Symbol: Ω. A unit of electrical resistance or impedance. One volt produces a current of 1 amp. in a resistance of 1 ohm. The international ohm is the resistance of a uniform column of mercury 106·3 cm. long and weighing 14·452 grams. See RESISTANCE.

OHMMETER. An electrical instrument for the measurement of resistance by direct reading. It usually contains either a battery or a generator so that no separate supply is needed. One type consists essentially of a current-measuring device scaled in terms of resistance, while in another form the deflection depends on the ratio of voltage to current. The latter is a true ohmmeter. See MEGGER TESTER.

OHM'S LAW. The electrical law in which is expressed the fact that the steady current in a circuit is directly proportional to the e.m.f. and inversely proportional to the resistance. Therefore, in a circuit in which D.C. is flowing, it is possible to calculate in the following simple

manner the value of voltage, current or resistance, if any two are known. The formula is:

$$I\ (\text{Amps}) = \frac{E\ (\text{Volts})}{R\ (\text{Ohms})}.$$

See RESISTANCE.

O.H.V. An abbreviation of the term overhead valves. See VALVES AND VALVE GEAR.

OIL. A term which includes most liquids that will not mix with water; in general, oils will mix with alcohol, and they are combustible. The principal classes are (1) vegetable and animal oils which are fatty in properties and are derivatives of glycerine, (2) mineral oils which are mixtures of hydrocarbons, (3) essential oils obtained from plants; these are sweet-smelling and are usually mixtures of terpenes and camphor-like substances. See FATS.

OIL CLEANER. A filter through which all oil must pass before it can enter into the pump for circulation in the lubrication system of a machine or engine. See FILTER.

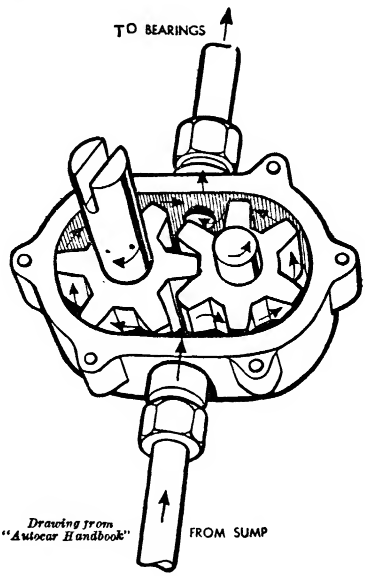
OIL-CONTROL RING. A ring fitted below the compression rings on the piston of an internal-combustion engine. Its purpose is to scrape excess oil from the cylinder wall and direct it back to the sump through a number of holes drilled in the side of the piston just below the ring. It is sometimes known as a scraper ring.

OIL GILDING, see GILDING.

OIL PAINT. A term used to indicate paint in which the pigment, or solid ingredient, is ground in genuine, refined linseed oil. To this paste are added driers, a further quantity of linseed oil, and genuine turpentine or white spirit, to create a sufficiently fluid condition for extension as a film of even thickness by application and manipulation with brushes or by diffusion with a spray equipment. Its special uses are to protect the surface to which it is applied from disintegration and mechanical damage.

OIL PUMPS. The most popular type of pump, shown in the diagram, is commonly used in the lubrication systems of internal-combustion engines. It consists of a pump casing in which rotate two small-toothed wheels. One of the wheels, free to turn on its spindle, is driven by the second wheel through the centre of which passes a driving shaft connected by gearing to the camshaft by which it is rotated.

As the pump rotates, oil is sucked through the intake pipe from the sump supply and is forced through the pump as indicated by the arrows. From the outlet side of the pump, oil is delivered to bearings and other parts to be lubricated in a more



Drawing from "Autocar Handbook"

Type of lubrication pump in general use on internal-combustion engines.

continuous flow than is provided by other types of oil pump which are of the plunger variety.

OIL-RELIEF VALVE. A device which controls the pressure of a force-feed oiling system. The unit consists of a spring-loaded valve; the tension of the spring, which is adjustable, allows the pressure of the system to be varied according to requirements.

An excessive pressure of oil in the system causes the valve to be lifted

off its seat, thus relieving the oil, which returns to the sump.

OIL SAND. Sharp sand, that is sand free from clay, to which linseed oil, molasses or other core binders (q.v.) have been added to provide cohesion. Such a sand mixture is very strong when stoved and is much more permeable than ordinary sand mixtures. It is, therefore, most suitable for the manufacture of cores, the great strength often making reinforcement unnecessary.

Sands bonded with straight oils have little green-bond, consequently metal cradles are required to support the cores during stoving. If additional green-bond is required, up to 15 per cent of red sand may be added to the mixture, but only at the expense of some loss of permeability. Alternatively, one of the semi-solid core binders may be used.

Oil sands flow freely, so little or no ramming is needed for hand-made cores, the sand being merely pressed into place with the fingers. Mechanical ramming presents no difficulties.

OILSTONE. Natural or artificial stone, smoothed and polished, used with oil for sharpening tools. Only the best mineral oil should be used, otherwise a skin forms on the stone. This can, however, be removed by wiping with paraffin or rubbing on emery cloth.

It is important to keep the stone clean and covered when not in use. Washita is considered to be the most satisfactory for general work, but Arkansas, Charnley Forest and Turkey are also favourite natural stones. Carborundum and Indian are popular artificial stones, and may be obtained in different degrees of coarseness.

Finger slips, or small sharpening-stones suitable for holding in the hand, for gouges and spokeshaves, are made of the same materials. The use of an oilstone in connexion with the sharpening of a plane iron, and also a typical finger slip, are illustrated under the heading Plane.

OLEIC ACID, see Fats.

ONE-PIPE SYSTEM, see Drainage.

OPACIFIER. Any material incorporated or used in an enamel to produce a high degree of whiteness. The true whiteness of enamel is technically known as opacity (q.v.), or opaqueness, and the enamel is commonly measured for this quality in terms of percentage reflectance, using pure magnesium oxide as the standard for comparison.

Opacifiers most commonly used to produce whiteness or opacity in enamels are oxides of tin, zirconium and titanium. These oxides are usually added in varying proportions to the enamel during the process of milling it to the required fineness. There are also numerous synthetic opacifiers made from various materials which often give good opacity when used with certain enamels.

OPACITY (Painting). The obscuring property of paint, which may be lost by the over-thinning of the paint or the use of a pigment which is more or less transparent when ground in an oil medium.

OPEN AREA. When floors are situated below the outside ground level, in order to keep the floor and compartment free from damp, special treatment is required in the construction of the external wall. In some circumstances this may be accomplished by the insertion of a continuous damp-proof course through the

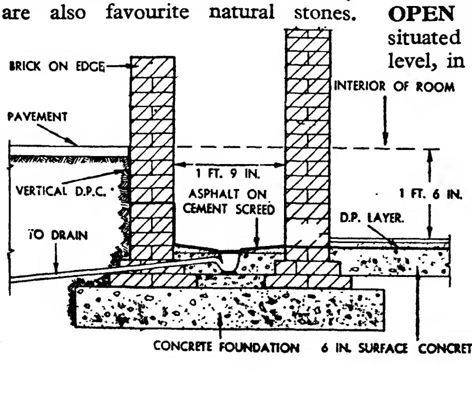


Diagram showing construction of open area.

external wall and by extending it vertically above the ground level.

Alternatively, when site conditions permit, a space may be formed in front of the external walls by excavating the ground below the floor level and building a retaining wall to support the earth. The floor can then be constructed in the ordinary manner. See AREA.

OPEN CIRCUIT, see CIRCUIT.

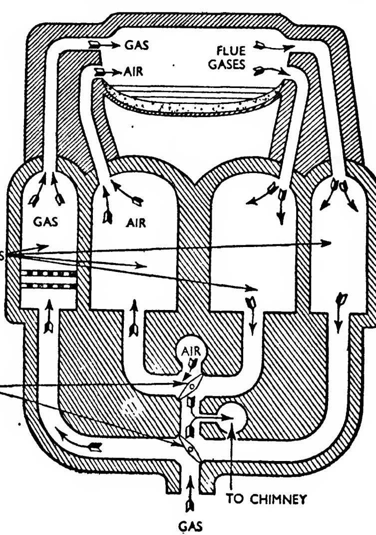
OPEN EAVES, see EAVES.

OPEN-HEARTH PROCESS. The method of manufacturing steel by refining a charge of pig iron (Siemens Process), or a mixture of pig iron and steel scrap (Siemens-Martin Process), in an open-hearth furnace.

This type of furnace was developed by Sir William Siemens, who took out his original patent in 1856. It uses gas as a fuel, both the gas and the air necessary for combustion being preheated on the regenerative principle. The gas may be obtained from a gas producer, coke ovens, blast furnaces, town supply etc. Preheated air and gas enter the working hearth at one end of the furnace through separate ducts as shown in the accompanying illustration. The flue gases pass out at the other end of the hearth through a pair of regenerators.

Two pairs of regenerators are necessary, the direction of flow of both gas and air being reversed periodically. In this way much of the heat present in the flue gases is transferred to the incoming gas and air, resulting in economy of fuel and a higher temperature in the hearth. The lining of the furnace may be either acid or basic according to the type of steel being made (see ACID STEEL and BASIC STEEL). In the acid process the capacity of the furnace is generally about 40 tons but may be as great as 100 tons.

Somewhat larger furnaces are used in the basic process, the more usual size being 150 tons and the largest about 400 tons. In operation, the charge of pig iron, or pig iron and steel scrap, is first melted. The impurities carbon, silicon and manganese are slowly removed by contact with the oxidizing slag which is maintained in an active state by addition of hæmatite iron ore, or other oxides of iron.



Sectional view of open-hearth furnace showing ducts for passage of air and gas.

When these elements have been almost entirely removed, a process which may take up to about 16 hours, the proportions of carbon and manganese in the charge are adjusted by adding ferro-manganese, the addition at the same time removing most of the oxygen in the melt.

Complete deoxidation is obtained by additions of ferro-silicon or aluminium. In the acid process, the impurities sulphur and phosphorus are not removed, consequently it is essential for the charge to contain only low proportions of these elements. Considerable amounts of phosphorus may, however, be removed in the basic process, but it is then essential to remove the slag before deoxidation or the phosphorus will be returned to the melt.

OPERATIONAL CEILING, see CEILING.

OPTICAL FLAT. A glass or quartz plate having perfectly smooth,

parallel surfaces, used to gauge surface inaccuracies which are too small to check with a micrometer.

In general it is possible to detect with ease differences of 0·00001 in. directly, or from 0·000001 in. to 0·000005 in. by estimation, up to a total difference of approximately 0·0008 in.; but where surface irregularities exceed a total difference of 0·0008 in., then the surface is too coarse for measurement by this means. Where surfaces have to be flat to within limits of ten-thousandths or even hundred-thousandths of an inch, on the other hand, the micrometer becomes almost useless for checking purposes owing to the presence of variable pressure and backlash.

Briefly, the principle of optical flats is based on the fact that if the plate is put into close contact with the surface of another plate, a series of coloured bands will be visible, and these will indicate the inaccuracies of the surface being checked. These coloured bands are produced by the interference of light reflected from the two contacting surfaces, and are usually referred to as interference fringes. The distance between each two interference fringes represents a surface inaccuracy of 0·00001 in., so that the arrangement and spacing of the fringes provides what is in effect a coloured contour map of the surface being checked.

While it is impossible to give here a complete description, with all necessary formulæ, of the various methods of using optical flats, it will be of value to consider how certain well-known types of surface conditions may be recognized.

In the illustration a circular optical flat has been used to check five different surfaces, and the following points should be noted:

(a) This surface is spherical, as the rings are more widely spaced at the centre than at the edges. Moreover, as there are four colour fringes visible from the centre to the edge of the flat, it is known that the surface is convex or concave by $4 \times 0{\cdot}00001$ in. $= 0{\cdot}00004$ in. The user can discover whether the surface is convex or concave by pressing with the finger tip on the optical flat at the centre of the rings. If the coloured bands now move away from the finger the surface is convex, but if they move inward towards the finger the surface is concave.

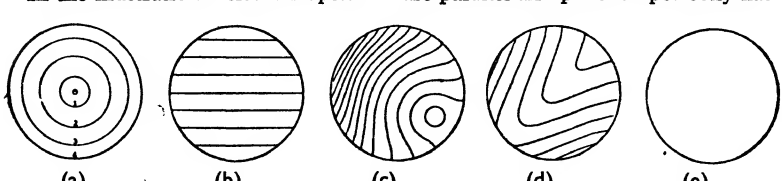
(b) This is a perfectly flat surface, but the optical flat is not in close contact with the surface being checked. There is a wedge of air between the two surfaces which is 0·00007 in. higher at one end than the other, revealed by the fact that there are seven interference fringes visible, all parallel and equidistant.

(c) This surface has a ridge or valley with its highest or deepest point near the right-hand lower edge of the optical flat. Finger pressure will determine the condition.

(d) This surface has a ridge or valley running from the lower left to the upper right of the surface. Finger pressure will again determine the condition.

(e) This is a perfectly flat surface in close contact with the optical flat, as no colour fringes are visible.

Finally, as an indication of the degree of accuracy necessary in producing optical flats, it may be noted that the two working surfaces are parallel and polished perfectly flat



OPTICAL-FLAT TEST FOR GAUGING SURFACE IRREGULARITIES
Diagram showing use of optical flats to check surfaces, as explained in the text.

to within 0·000002 in. (two-millionths of an inch).

OPTICS. The science of light. The most important facts established about light are: light rays travel in straight lines; when light is reflected the angle of incidence (i) is equal to the angle of reflection (s); when light passes from a lighter to a denser medium it is refracted (bent toward a line drawn perpendicular to the surface).

For any two transparent materials $\frac{\sin i}{\sin s} = u$, a constant known as the *index of refraction.* Light passing from a denser to a lighter medium follows the same path, so that the index of refraction $= \frac{\sin s}{\sin i} = \frac{1}{u}$. Light consists of waves of different wavelengths, each wavelength representing a particular colour.

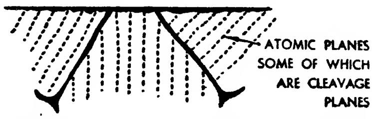
White light is a mixture of the spectrum colours red, orange, yellow, green, blue and violet. All wavelengths travel at the same speed—186,000 miles per second. See REFRACTION.

OPTIMUM LOAD (Radio). Generally, the value of impedance which, when connected in the anode circuit of an output valve, develops the maximum output power at a given low value of distortion. In the case of single triodes this is approximately twice the A.C. resistance of the valve, while for pentodes it is somewhat more indeterminate.

The term is also used in connexion with voltage amplifiers, when it may be taken to mean that value of load impedance which gives the maximum possible stage gain with an agreed distortion limit.

ORANGE CHROME, see CHROMIUM.

ORIENTATION. The direction in which the planes of crystals lie in a metal, i.e. the direction of the crystallographic axes. Each crystal in a metal is built up from a number of atomic layers or planes lying parallel to one another like cards in a pack. Neighbouring crystals have different orientations, as shown in the illustration,



Showing direction in which planes of adjacent crystals in a metal may lie.

and it is to this fact that a metal owes its resistance to deformation.

In any crystal under stress, slip is liable to take place along certain planes of weakness, known as cleavage planes, and single crystals are thus relatively weak. The aggregate of crystals constituting a mass of metal is strong because the crystals, and therefore their cleavage planes, have different orientations. *Preferred* orientation, due to elongation of the crystals in the direction of rolling, is a cause of weakness in sheet metal. See DIRECTIONALITY.

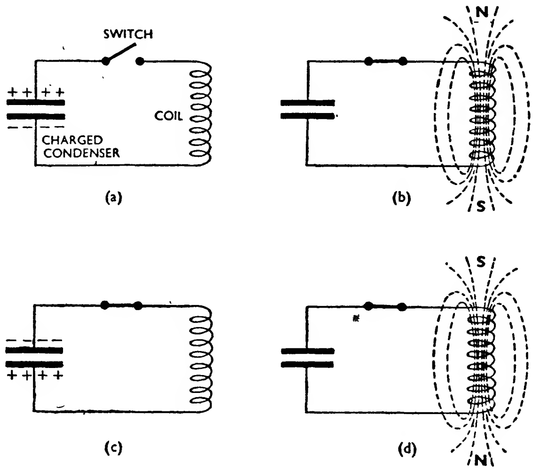
ORNITHOPTER. A form of flying machine which was lifted off the ground and propelled forward by wings which flapped like those of a bird in flight. Man's early attempts at flight, like those of Dædalus and his son Icarus in Greek mythology, who built themselves wings of feathers and beeswax, were by means of ornithopters.

No machine of this type yet produced has proved successful. The nearest approach to bird flight is in the sailplane, which is similar to the gliding birds, like the albatross, though, of course, it is incapable of lifting itself off the ground.

ORTHOCLASE, see FELSPARS.

OSCILLATION. A phenomenon in an electric circuit containing inductance and capacitance. The various phases are illustrated in the diagram overleaf. Suppose a condenser to be charged from a D.C. source which is subsequently removed. The condenser is now a seat of stored potential energy.

Next, suppose a coil to be connected in parallel with the condenser. A discharge current immediately flows, setting up magnetic flux around the coil, and the magnetic field so produced now contains, in dynamic form, the energy previously held by the



Phases in a cycle of oscillation: (a) potential energy is stored in the condenser until switch is closed; (b) condenser then discharges and energy is transferred to magnetic field surrounding coil; (c) magnetic field collapses and condenser again becomes charged, its polarity this time being reversed; (d) condenser discharges again; energy in the circuit, now in kinetic form, is in a magnetic field of polarity opposite to (b).

condenser. This condition is unstable, the magnetic field collapses and the resulting e.m.f. drives a current into the condenser which now becomes charged with opposite polarity. It again discharges through the inductance and, in the absence of loss, the whole cycle of events repeats itself indefinitely.

The electrical oscillations so produced represent an interchange of energy between condenser and inductance. The frequency of oscillation is determined by the inductance and capacitance of the circuit and is given by $f=\frac{1}{2\pi\sqrt{(LC)}}$ where L is the inductance of the circuit in henrys and C the capacitance in farads. Such oscillations are the basis of radio transmission.

OSCILLATOR. In radio apparatus, a circuit arrangement, usually incorporating an amplifying valve, for the generation of continuous oscillations. It forms the "heart" of nearly all radio transmitters and is used in reception for many purposes, including frequency changing and the production of beat frequencies.

OSCILLOGRAPH. One of the peculiarities of electrical work is that there is normally nothing to see. Unless it is overheating and getting red-hot, wire looks just the same whether it is carrying a current or not and many people have found to their cost that they cannot tell whether a terminal is alive by looking at it. Because of this, the behaviour of electrical circuits must be inferred from the readings of instruments, the results of experiments, or, more easily, by means of an oscillographic device.

Strictly speaking, an oscilloscope shows a picture, while an oscillograph makes a permanent record. As it happens, many machines will do both, so the term oscillograph is here used to mean them all.

One of the earliest instruments which might be called an oscillograph was the Joubert Contact Maker (see JOUBERT CONTACT). This contrivance is so arranged that a voltage is connected to a voltmeter or an electrometer and a condenser, for a very short time, at exactly the same instant in successive cycles of an alternating voltage. Neglecting leakage the condenser charges-up until its voltage is the same as the instantaneous value (see ALTERNATING CURRENT) of the voltage being investigated and the voltmeter accordingly reads that value. By moving the fixed contact shown in the diagram included with the entry JOUBERT CON-

TACT, the contact may be made at any chosen instant in the cycle. In this way a whole series of instantaneous values may be measured, and, on plotting them, a picture of the waveform of the unknown voltage is obtained.

A variation of the Joubert method is the Ondograph. In this machine a mechanical device is provided which produces the effect of moving the fixed Joubert brush slowly round. The voltmeter is of the recording variety and it is thus able to draw a picture of the waveform on a piece of paper mounted on a slowly revolving drum.

Both these pieces of apparatus have the disadvantage that they are not responsive to transitory changes in waveform, that they are slow in use, and that they are unsuitable for the higher frequencies.

Let us now consider the requirements for an electro-mechanical oscillograph. There must first be a narrow beam of light, produced usually by means of an electric-arc lamp. This beam is directed on to a small mirror, which is caused to oscillate in sympathy with the variations in current. Provided that the movement is light enough and has a relatively high natural mechanical frequency, there is no great difficulty in making the mirror follow the current faithfully at power frequencies and the lower audio-frequencies.

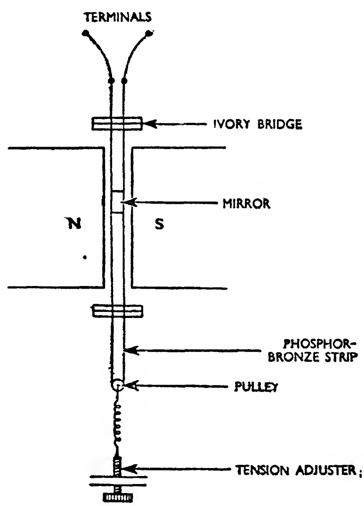
After the light has been reflected from this mirror it is in the form of a band, such as would be obtained if a piece of corrugated iron were squashed concertina-wise.

To spread the beam out into a waveform it must be given another motion, at right-angles to the first one, at a constant speed. One way of doing this is to project the band of light on to a moving film or photographic plate, which moves vertically if the band is horizontal. When the film is developed, the picture looks like the edge view of the piece of corrugated iron before it was squashed.

For visual observation the beam of light itself must move. This can conveniently be arranged by causing it to fall on a long narrow mirror which moves about an axis parallel to its length. If the light is reflected on to a ground-glass screen the spot traverses the waveform, and, owing to persistence of vision, the whole wave is seen at once.

In practice the mirror oscillates with a quick-return motion. During the forward stroke the mirror turns at a constant speed while the waveform is traced out. It then returns quickly to the starting point. To avoid confusing the picture the light may be cut off during the fly-back period.

The only point that remains is to ensure that one cycle of mirror movement corresponds with one



In an oscillograph, when current is passed through the phosphor-bronze loop, one side moves in one direction, the other in opposite direction. As a result, the mirror is twisted. A high natural frequency is secured by using considerable tension and by means of bridges to limit the vibrating length.

cycle, or, at least, a whole number of cycles, of the alternating current. If this were not done, the picture would appear to wriggle across the screen.

The apparatus which translates the alternating current into a mirror

movement may depend upon any of the usual methods. The most common arrangement, which is similar in principle to the moving-coil instrument (q.v.) is illustrated in the accompanying diagram. Other oscillographs have been constructed which work on the electrostatic and the hot-wire systems.

Most electromagnetic oscillographs are provided with two or more movements so that it is possible to examine simultaneously, say, a current and a voltage or a power curve. In switchgear testing as many as sixteen traces may be made at the same time.

The most modern development is the cathode-ray oscillograph (q.v.).

OSCILLOSCOPE. An electrical apparatus for producing a visual indication of the waveform of an electrical quantity such as a voltage or current. See OSCILLOGRAPH.

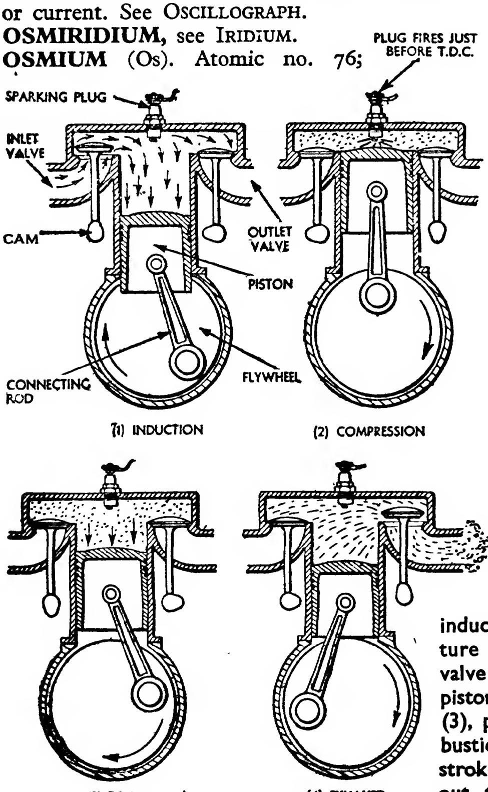
OSMIRIDIUM, see IRIDIUM.

OSMIUM (Os). Atomic no. 76; atomic wt. 191·5. A very hard whitish metal with a density of 22·48. It melts at about 2400 deg. C. It is chemically similar to platinum and iridium, and forms a hard alloy with iridium. It is octavalent and forms oxides OsO_2, Os_2O_3 and OsO_4. The last is soluble in water, forming osmic acid, used as a stain for microscopic preparations. Three fluorides of osmium are known: OsF_4, OsF_6 and OsF_8.

OSMOSIS. The spontaneous flow of liquids through a membrane. Many membranes are semi-permeable, that is, they permit the flow of some liquids but not all, and some liquids will permeate the membrane quicker than others.

Consequently if a semi-permeable membrane separates two different liquids, such as a weak solution and a strong solution, it often happens that more liquid flows through the membrane in one direction than in the opposite direction; a pressure is thus set up known as the osmotic pressure.

OTTO CYCLE. When an explosive mixture of fuel and air is first compressed within the cylinder of an internal-combustion engine and then ignited, it yields more energy than is required to overcome its resistance during compression. Consequently, it is



In modern internal-combustion engines working on the four-stroke principle, the sequence in each individual cylinder is as follows: induction stroke (1), air/fuel mixture is drawn in through inlet valve; compression stroke (2), piston ascending; power stroke (3), piston forced down by combustion of mixture, and exhaust stroke (4), burnt gases are forced out through the exhaust valve.

an advantage to work an internal-combustion engine with a compressed charge. The Otto cycle, or four-stroke cycle, takes its name from a German engineer who first put it into practice. It consists of induction, compression, power, or combustion, and exhaust strokes and requires two complete revolutions of the crankshaft, or two "up" and two "down" strokes of the piston, to complete the cycle of operations. These are shown in the diagram on the opposite page.

Induction Stroke: the piston starts its downward movement in the cylinder and, by the action of a cam on the camshaft, the inlet valve opens slightly before top dead-centre. The mixture is drawn into the cylinder from the carburettor and the inlet valve closes after the piston has completed its downward stroke.

Compression Stroke: the piston travels up the cylinder and, as both inlet and exhaust valves are closed, the mixture is compressed within the cylinder. As the piston reaches the end of the upward stroke and the gases are fully compressed, the spark is introduced into the cylinder, igniting the charge.

Power Stroke: as the resulting explosion from the ignited charge causes the gases to expand very rapidly, they act with great force on the top of the piston and drive it down. The piston is coupled by the connecting rod (q.v.) to the crankshaft, a turning effect being thus applied to the latter. Just before the piston reaches the bottom of its stroke the exhaust valve opens so that the burnt gases can escape.

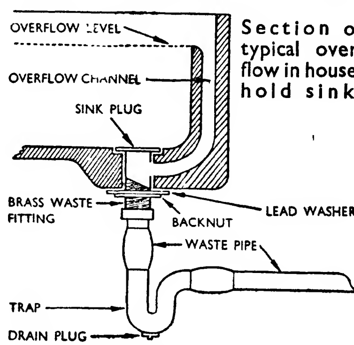
Exhaust Stroke: the piston travels up the cylinder and the used gases are swept out through the open exhaust valve into the exhaust system. When the piston reaches the end of its upward stroke the exhaust valve closes and the cycle of operations is repeated.

OUTFLOW. An aircraft propeller exerts a thrust by accelerating, relative to itself, the air that passes through its disk. Thus, if we imagine the aeroplane to be stationary and the air to be flowing past it, the air behind the propeller will be travelling faster than that in front of it. Roughly half of this increase in velocity takes place behind the propeller and this difference in speed is called the outflow or outflow velocity. See INFLOW.

OUTFLOW VELOCITY, see OUTFLOW.

OUTPUT (Radio). Generally, the term applied to the A.C. power available at the anode circuit of a radio valve. Also, the term is more broadly used in connexion with voltage, current or power available from other A.C. and D.C. sources.

OVERFLOW. A pipe or other arrangement for the purpose of getting rid of water in a cistern, sink,



Section of typical overflow in household sink.

lavatory basin etc., when the water rises above a safe level: a secondary exit to a water container, so arranged that water cannot flow through it until it reaches the level required.

The illustration gives a sectional view of a weir-type overflow cast integral with a sink. Normal drainage occurs when the sink plug is removed from the waste-pipe fitting, but should the tap be left running while the plug is still fixed, water will be discharged automatically to the waste pipe down the overflow channel as soon as it rises to the appropriate level.

Various types of overflow are in use, sometimes, as in cisterns, taking the form of a separate pipe exit which discharges the water outside a building. This system also provides a

warning that the cistern is overflowing.

Overflow pipes to cisterns should be at least twice the diameter of the inlet pipe, and should be fixed through the side at a point slightly lower than the inlet to prevent the possibility of siphonage back through the service pipe in the event of that pipe being emptied.

OVERHANG RATIO. The distance from the fuselage side or wing root of an aircraft to the wing tip divided by the overall depth at the root. The choice of overhang ratio, an average value of which is about 18, rests on a compromise between two conflicting requirements. To obtain a low drag a thin wing is required; this means a large overhang ratio, but a large overhang ratio gives large loads in the spar flanges, which requires much material and so gives a heavy wing.

OVERLAP, see TIMING GEAR.

OVERLOAD. A load on an electrical machine or other equipment which is greater than its rated load. While overloads are permissible, the period for which they may be sustained is strictly limited by heating. For example, a twenty-five per cent overload is often limited to two hours.

OXIDE PAINT. A term widely used to indicate paints in which the colour of the pigment is due wholly to inorganic iron compounds. The pigments, which vary in colour from dark red through deep purple to black, are permanent, inert and mix well with all other pigments. They are mainly used in an oil medium for external painting.

OXIDES. Combinations of elements with oxygen, usually classified as follows: acidic, basic, amphoteric, neutral and peroxides. This classification is chiefly of chemical interest; from the metallurgical point of view it is the basic oxides which are the most important. These are, in general, the oxygen compounds of the metals. Of special interest, however, is aluminium oxide, which is an amphoteric oxide, i.e. one which may behave either as an acidic or basic oxide. Metals may form more than one oxygen compound; e.g. iron forms three—ferric oxide, ferrous oxide and magnetic oxide. Copper forms cupric and cuprous oxides.

It is frequently as oxides that metals occur in nature, and the extraction of the metal consists in reducing the oxide with a substance such as carbon. Thus the iron ore, hæmatite, is mainly ferric oxide, and magnetite is chiefly the magnetic oxide of iron.

In the fabrication of metals, oxides are usually a cause of trouble in one way or another. Thus, in heat treatment the metal combines with atmospheric oxygen to form a scale which must be removed before any finishing process can be carried out. In the joining of metals oxide films may prevent good adhesion and must be removed by the use of a flux (q.v.). In most corrosion processes the oxygen in the air combines with the metal to form oxidation products such as rust. Oxides may be included in the metal during manufacture, and may cause irregularity in the finished product.

One of the useful oxide films is aluminium oxide, which is formed artificially, and which enables aluminium and its alloys to withstand corrosion to a surprising extent. Moreover, the oxide film on the aluminium may be extremely hard and confer good resistance to wear on the aluminium. Oxide films are produced chemically as methods of colouring metals. Iron and copper may be coloured black by suitable treatments. Metal-oxide films are used in certain types of rectifier.

OXY-ACETYLENE WELDING. A fusion-welding process in which the heat produced by an oxy-acetylene flame is employed to melt together the edges of the metal to be joined. Additional filler metal from a welding rod may be added to the molten pool during welding in order to ensure that the thickness of the joint is at least equal to, and preferably a little greater than, the thickness of the parts being joined. Almost all the commercially used metals can be

welded, and the process is used for making joints in metal sheets, plates, tubes and sections; for repairing cracked or broken castings or other broken parts; and for depositing metal in order to rebuild worn parts or to apply wear-resisting surfaces.

Although welding usually involves the melting (i.e., full fusion) of the edges or surfaces to be welded, metals can be joined and metal deposited by a non-fusion technique. This necessitates the use of a welding rod, consisting of a metal having a lower melting-point than that of the metals to be joined. The welding rod is usually bronze, and the technique is largely employed in the repair of malleable and ordinary iron-castings; it can, however, be used for joining steel sheets or sheet steel to thicker plates or sections. It is also useful for the joining of steel to cast-iron or copper, or copper to brass, or for joints in copper sheets, the melting point of these metals being higher than that of the bronze (in reality a brass) welding rod.

A partial fusion technique using an excess acetylene flame is also employed for the deposition of wear-resisting or hard-surfacing metals on to steel parts and surfaces.

OXYGEN (O). Atomic no. 8; atomic wt. 16. The most widely distributed and commonest of the elements; it forms about 23 per cent of the atmosphere, about 8 per cent of water, about 48 per cent of chalk and limestone and about 53 per cent of silica, sandstone and many volcanic rocks.

Oxygen is a colourless, odourless gas that can be condensed to a bluish liquid, boiling at −182 deg. C. at 760 mm. of mercury (atmospheric pressure). It freezes to a solid at −227 deg. C. On a small scale oxygen is conveniently made by heating potassium chlorate, $KClO_3$, mixed with manganese dioxide, MnO_2, the latter acting as a catalyst. On the large scale it is made by the distillation of liquid air. The more volatile nitrogen distils off more readily than the oxygen, and it is easy to obtain a gas rich in nitrogen and a gas rich in oxygen.

By redistillation, oxygen containing only about 3 per cent of nitrogen can be obtained. The oxygen of the atmosphere is essential for the respiration of animals and for the combustion of fuels. Oxygen is a mixture of three isotopes with masses of 16, 17 and 18; of these the first forms about 99·76 per cent of the total. Molten silver dissolves about ten times its volume of oxygen and emits the oxygen as it cools.

Oxygen is used in medicine, being breathed by persons who have been suffocated or poisoned by carbon monoxide or who need some temporary stimulus. Oxygen combines with most of the metals and non-metals to form oxides. Many of the oxides combine with water to form acids, but some of the oxides, e.g. those of sodium, potassium, calcium and barium, are basic or alkaline.

In industry, oxygen is widely used for cutting metals. For this purpose one blowpipe is utilized to mix oxygen and acetylene, the resulting flame having a temperature of more than 4000 deg. C., while a second blowpipe is employed to provide a jet of "cutting" oxygen close to the heating jet. When the cutting jet is moved regularly backwards and forwards across the metal to be cut, a smooth even cut is obtained. By this process, metals of considerable thickness may be dealt with.

OZONE (O_3). An allotropic form of oxygen. It is a gas with a pale blue colour, and can be condensed to a blue liquid that boils at −112 deg. C. Oxygen containing ozone is obtained by passing oxygen through tubes or plates between which an electric brush discharge is maintained.

Ozone at temperatures above about 90 deg. C. is transformed into oxygen. It is an oxidizing agent and removes the smell of many animal and vegetable substances. It is not known to be in any other way a useful constituent of the air; the smell of the seaside is due more to decaying seaweed than to the presence of ozone.

PAINTERS' BRUSHES. The characteristic tools of the painter, shown in the accompanying illustrations, consist of a bunch or knot of bristles or hairs attached by string, wire, metal ferrule or by insertion, to a wooden handle. Their size and shape vary with the requirements of the operation to be undertaken, but in all brushes the bristle portion must be fairly stiff yet flexible and must retain these qualities when wetted with water, oil or spirit. The attachment must be secure and neatly finished and the handle convenient for holding.

A good brush, which is a sound investment if carefully selected for suitability to purpose and likelihood of lengthy service, cannot be obtained cheaply. Some brushes are named from their construction, but most are called after the work they are to execute. *Dusting* brushes have fairly soft bristles from four to six inches long and may be circular or rectangular in arrangement.

The *Limewash* brush is generally known as a turk's head; its bristles are arranged round the base of a cone-shaped block of wood; holes in the side and apex enable it to be fixed to the end of a long staff. Such an arrangement enables the worker to cover large areas with the minimum of scaffolding.

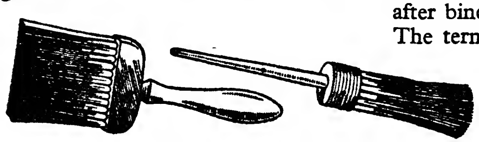
Distemper brushes are large and flat, from 6 to 8 in. wide with bristles of the same length fastened to the wood handle either by a leather strip and nails or by a metal ferrule. For washable distempers and water paints the bristles form a more compact mass than those required for use in glue-bound distemper. *Knot* brushes have the bristles arranged in round or oval bunches and may consist of one, two or three attached to the same handle. Two- and three-knot brushes are used mainly for distempering, the single-knot brush for oil painting. If made for varnishing, the bristles form a more compact bunch and have the ends ground off so that they are suitable for use in varnish without any preliminary breaking in.

Flat paint brushes have almost completely replaced the knot brush for the application of paint. They are composed of a flat, compact mass of fine, black bristle attached to the handle by a metal ferrule. The maximum width for satisfactory use in paint upon large surfaces is 4½ in., for smaller surfaces they diminish by ½ in. stages down to 1 in.

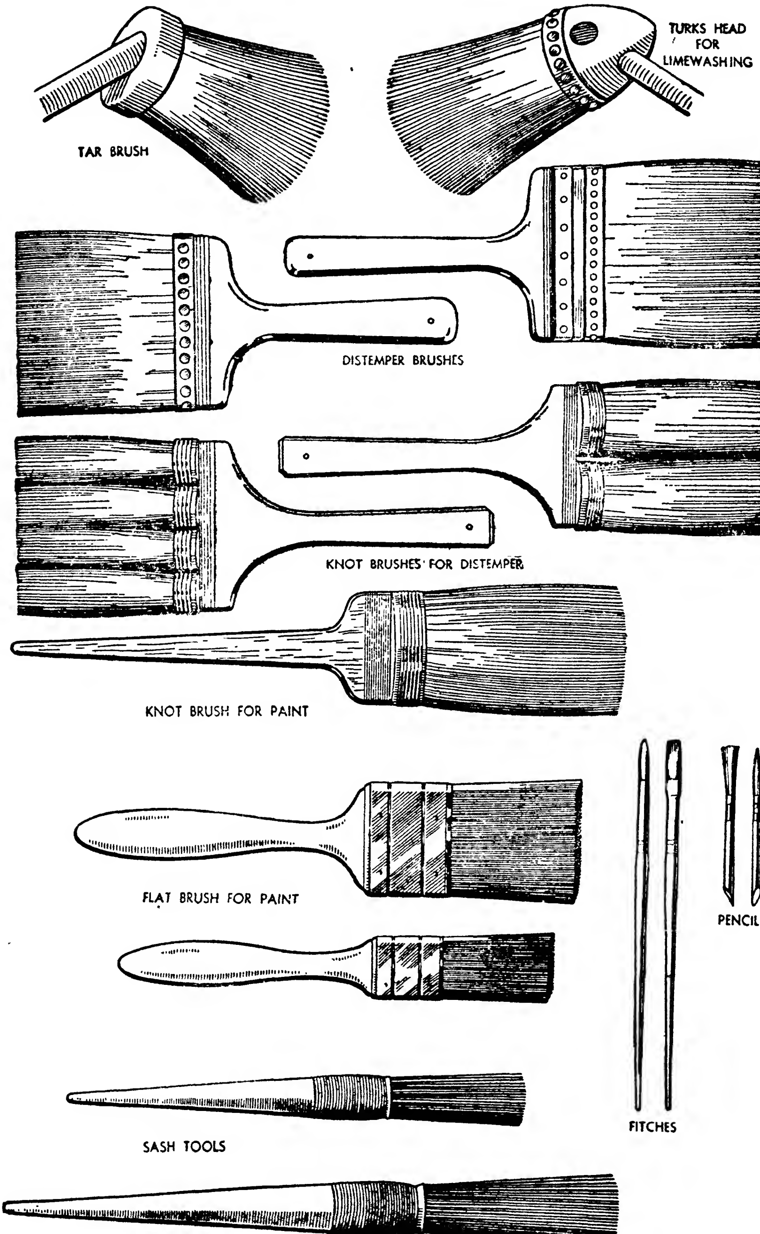
Sash tools are circular single-knot brushes of smaller size attached to long handles, formerly used both in distemper and oil painting; now practically restricted to use in distemper work. The largest are 2½ in. in diameter with bristles 5 in. long, the smallest being ½ in. in diameter with bristles 3 in. long.

Fitches. Small brushes with the bristle or hair attached to long thin handles. In section they are round, oval or flat. The largest are 2 in. wide, with the exposed bristle not longer than 2 in., while the smallest are ¼ in. in width with bristle about ½ in. long. The hair of many fur-bearing animals is used in their making.

The smallest brushes used by decorators are known as *pencils*. They have the knot of fine hair either attached to the long thin handle with a metal ferrule or inserted into a quill after binding with silk, wool or wire. The term "camel hair" has by long usage come to mean the softer types of hair used in brush making, from whatever source they are derived. Fitches and pencils made from soft



Dusting brushes, which have soft bristles about 4 to 6 in. long, may be either round or flat.



PAINTERS' BRUSHES FOR VARIOUS PURPOSES

Careful choice of brushes is essential for the best results. Numerous types, some of which are shown above, are available, each brush having its specific purpose.

hair are suitable only for floating washes of very thin colour. Sable is hair of a much stiffer character and is utilized in making brushes which will carry and extend colour containing heavy pigments.

PAINTING. A means of providing surfaces with both protection and decoration. The paint can be applied by dipping, spraying, or brushing on (see AEROGRAPH and PAINTERS' BRUSHES). Large castings and car bodies are frequently dipped in tanks containing specially prepared paints. Spraying is done by means of nozzles through which the paint is forced and atomized by compressed air. There is also available a pneumatic paint brush (q.v.).

All surfaces for painting must be thoroughly cleansed of rust, dirt and grease, if necessary with chemical solvents; old paint should be removed either by burning off or by means of a liquid paint remover. Knots and resin spots in wood should be coated with knotting (q.v.). The priming coat is the most important part of the preparation of the surface. The viscosity of the priming is governed by the porosity of the surface to which it is to be applied.

After priming, the grain of soft woods should be treated with fillers (q.v.). With oil colours and enamels, four thin coats are better than two thick coats; but with water colours and distempers, one thick coat is best. Cellulose paints are best applied by spraying; if brushed they must be applied quickly, no attempt being made to work out with the brush.

Faults in paintwork may be ascribed to lack of skill on the part of the operative, unsuitability of the material for its purpose, or the unsatisfactory nature of the ground upon which the material has been placed. The more common faults, dealt with under separate headings, are: Fading, Flaking, Efflorescence, Lack of Opacity, Pinholing and Pockmarking, and Stains.

When painting new *galvanized iron* special preparation of the surface is required. It should first be brushed down with wire brushes to remove all foreign matter such as mortar, cement etc. and then coated with a solution of acetate of copper formed by dissolving 8 oz. of the acetate in a gallon of water. When dry, excess of the precipitate is brushed-off with a dry dusting brush and the surface primed with red-lead priming paint, followed by two coats of red-lead paint, modified by the addition of pigments ground in linseed oil to obtain the required colour.

Should the finish have to be light-coloured, the red lead in the last two coats is replaced by genuine white lead ground in linseed oil. If galvanized iron has been exposed to weathering for six months, the treatment with acetate of copper may be omitted, but the surface must still be scoured with wire brushes and all rust removed before priming. See GALVANIZING.

PALLADIUM (Pd). Atomic no. 46; atomic wt. 106·7. A white, silvery metal, similar to rhodium and platinum. Density about 11·6; m.p. 1553 deg. C. It is divalent or tetravalent, forming an oxide, PdO, and sulphides, Pd_2S, PdS and PdS_2. The metal has a remarkable property of absorbing hydrogen, taking up several hundred times its volume of the gas. It forms an alloy with gold.

PALMITIC ACID, see FATS.

PANEL BEATING (Sheet-Metal Work). The art of forming sheet metal to shape for duct work, trunking and similar units. This is the earliest form of sheet-metal work. Although machine fabrication has very largely displaced hand work, the craft will not die for some time yet; with careful attention to pattern development (q.v.) it may actually revive.

For accurate handwork, it is necessary to have accurate layout work, extensive use of jigs, and careful calculation of the effect of such assembly processes as welding, which, by the introduction of heat, tend to distort lines and register.

PANEL DOORS, see DOORS.

PANEL HEATING (Building). A system of low-temperature direct radiation. Large areas of walls, piers

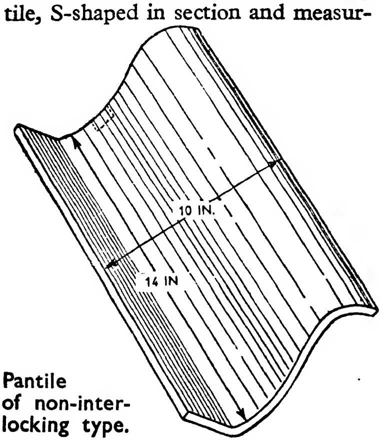
and ceilings are heated by means of small diameter pipes through which hot water circulates at a temperature ranging from 70 deg. to 130 deg. F. The pipes are secreted below the surface of ceilings and walls or concreted in the lower part of floor slabs.

Panel-heating systems should be thermostatically controlled so as to prevent the temperature being raised beyond the limit stated. A higher temperature will cause damage to the materials in which the pipes are embedded.

PANEL WALLS. Walls which form the clothing of skeleton-framed structures, so called because they fill the spaces between the vertical and horizontal framing members. They may be constructed with brickwork, hollow blocks, concrete or a combination thereof, or any other material which provides fire resistance.

Panel walls should be properly secured to the framework of the structure. They may comprise two skins or walls. The outer one should be impervious to keep out the moisture, and the inner one pervious to absorb condensation moisture given off by the occupants of the room. The cavity between the two skins may be filled with a lightweight concrete, or the space may be retained to assist as an insulating medium to heat and sound.

PANTILE. A special form of roofing tile, S-shaped in section and measuring 14 in. × 10 in. × $\frac{1}{2}$ in. thick. Pantiles may be either non-interlocking or interlocking, the former being hand-made and the latter machine-made. The tiles are obtainable in many colours, and are frequently used where a distinctive roofing effect is desired.



Pantile of non-interlocking type.

The lap or cover requisite for pantiles differs from that required for plain tiling in that it is single, and the tiles in each course cover the tiles in the preceding course by $2\frac{1}{2}$ to $3\frac{1}{2}$ in., according to the pitch. The bottom left-hand and top right-hand corners of the tiles are splayed, except in the case of eaves tiles and top tiles. See Roofing Tiles.

PAPER. An agglomeration of cellulose (q.v.) fibres which are matted in a layer to form a flexible sheet of even substance. Loading, sizing or colouring may be added, coatings applied or special finishings imposed to ensure suitability for specific purposes.

Several types of machine have been made for testing the bursting strength of paper, which is an important consideration in the printing industry. A typical example is the Mullen Tester, in which a small hydraulic glycerine-filled cylinder is covered by a flexible rubber diaphragm and connected to a pressure gauge. The paper to be tested is clamped over the diaphragm and pressure applied by turning a wheel. On the bursting of the test sheet, the gauge remains set until the pressure is released.

PAPERHANGINGS. Plain or decorated rolls of paper for large plastered surfaces. The standard width is 21 in. and a standard roll, if patterned, will cut into three 10 ft. lengths, four 8 ft., or five 6 ft.; slightly longer lengths may be obtained from plain papers.

The cheaper types, called *pulps*, are dyed during the process of manufacture; if patterned, some part of the original paper forms the background or part of the pattern. All better-class papers are termed *grounds* and have one colour applied over the whole surface before the pattern is printed. The pattern may be machine-printed,

in which case the whole of the colours are applied in one operation; or it may be block-printed, each colour being applied separately and at a different time, which adds materially to the cost.

Most paperhangings are printed in a distemper medium and are subject to the same disabilities as distemper painting; but some, printed in an oil medium, can, if care is exercised, be sponged down and cleaned in the same way as washable distemper. All papers are provided with selvedge edges which have to be trimmed off before the paper is hung.

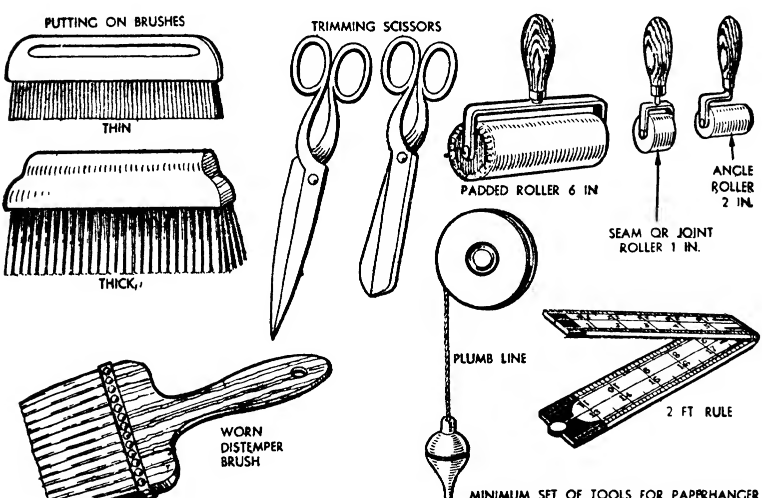
The adhesive used for hanging is stiff flour-paste made by beating 2 lb. of household flour into a smooth batter with one pint of lukewarm water; it is allowed to stand for half-an-hour and is then scalded with half a gallon of vigorously boiling water. The paste will stiffen at once, but before using should be set aside until cold.

Lengths of paper, slightly longer than the surface to be covered, are cut on a paperhangers' board which consists of two light planks, 6 ft. long and 1 ft. wide, hinged together and supported on trestles. In cutting up a patterned paper a satisfactory top is selected and care taken to ensure that, in succeeding lengths, the pattern matches along the butting edge.

The paste is applied to the back of the paper evenly and is well brushed-in; an excessive quantity of paste must not be left on the paper but sufficient must remain to enable it to be slid into position. Care must be taken not to skimp the supply of paste at the edges.

For convenience in handling, the pasted paper is turned over, back to back. The first length is hung to a perpendicular line, previously marked on the wall, and is brushed down into even contact. Any surplus at both ends is cut off and paste which may have touched the paint-work is cleaned off with a damp sponge and leather. When approaching an internal angle the paper is cut lengthwise to the width required so that it may bed-down easily.

Preparation of Surfaces: Dry, plaster surfaces are glasspapered to remove all roughness, dusted down and coated with weak, jellied glue-size in order to correct patchy porosity and

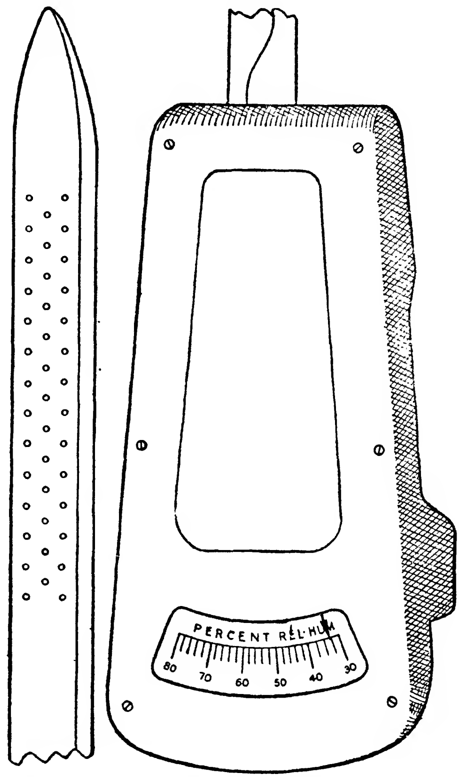


PAPERHANGERS' TOOLS
Various tools essential in paperhanging; their uses are described in the text.

to prevent excessive absorption of the adhesive paste. Distempered surfaces are washed-off clean to the plaster and sized in a similar way. In the case of a previously papered surface the old paper is thoroughly soaked with water and removed with a broad knife; the old paste is then removed by washing with hot water and the surface sized. Parian cement and other hard wall-plasters, after glass-papering and sizing, require interlining with a plain paper, butt joining, and hanging horizontally.

Painted surfaces are thoroughly washed with a fairly strong solution of sugar soap and cut down with a moderately coarse abrasive, washed with clean water and then sized and interlined with plain paper.

The essential *tools*, shown in the illustration, are: a worn distemper brush for pasting; a two-foot rule; a plumb bob and line; two pairs of scissors (11 or 12 in.), one pair double-pointed; two 10 in. paperhangers' putting-on brushes—one thin (two rows of bristles) and one thick (five rows of bristles); three rollers, one 6 in. felt-covered, one 1 in. boxwood elliptical-faced for joints and one 2 in. boxwood single arm for use in corners; and a sponge and leather. See EMBOSSED WALL COVERINGS.

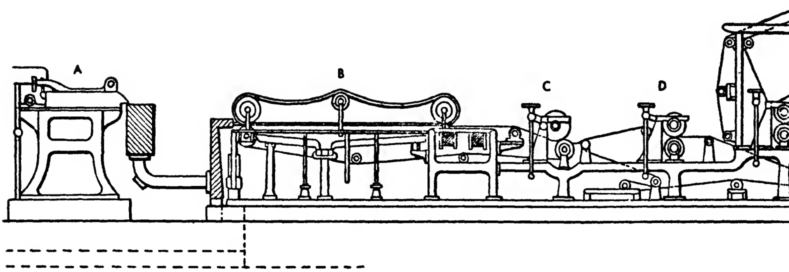


Hygrometers such as this are used to determine the amount of moisture in stacked paper by thrusting the perforated blade between sheets.

PAPER HYGROMETER. An instrument to determine the moisture content of paper. The sword type of hygrometer consists of a hollow perforated blade enclosing a moisture-sensitive element connected directly to the calibrated dial forming the handle, and thus giving a direct reading of the moisture content of the paper in terms of the percentage of relative humidity.

The test is made by inserting the blade into the stacked paper, when in a few moments the pointer will indicate the reading on the dial. This should be compared with a reading of the press room humidity, which will be registered on the dial on hanging the hygrometer in a suitable position. As paper can be quickly tested from ream to ream, or in various parts of the stack, its behaviour during printing can thus be accurately anticipated.

PAPER MAKING. The essential raw material from which paper is made is a fibrous substance called cellulose (q.v.). Theoretically all forms of plant life could be utilized for the extraction of cellulose for paper making, but commercial requirements of quantity and regularity of supply,



TYPICAL MACHINE USED

All paper, with the exception of special high-grade material, is now made by machine. The invention of such machines dates back to 1798 and they were introduced

cost of the raw stuffs, manufacturing costs and quality of the finished product, severely limit the choice of available raw materials. Cotton, linen, wood, esparto, hemp, jute, straw and waste paper are the main raw stuffs used in practice.

Economy is exercised by using cotton and linen rags, jute etc. The materials are then cleaned, blended and treated to give certain definite paper qualities. The varieties of paper are legion and every printing process and industrial, domestic and art purpose can be catered for. Much printing trouble and lost production time can be prevented by the choice of suitable printing stock, or paper.

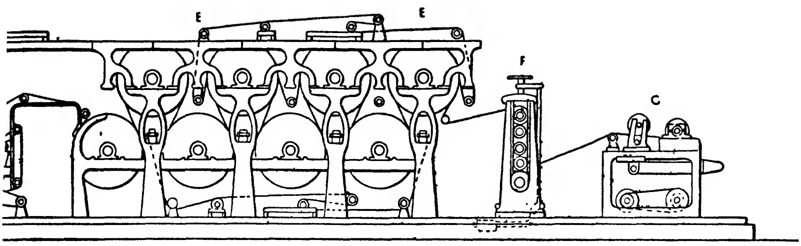
Not only does the choice of raw materials affect the quality of the paper, but the method of treating these during manufacture is of the greatest importance, because various results can be obtained from the same raw stuffs. Despite the varieties of paper the general manufacturing treatment is as follows:—

The raw stuffs are chosen, sorted and boiled in alkalis under pressure to remove the non-cellulose matter. Mechanical washing and partial breaking-down to fibres is followed by bleaching in chloride of lime or chlorine. Further washing and breaking is then carried out in the hollander engine, and the material is then known as *half-stuff*. After bleaching with chloride of lime the half-stuff is treated in the beating engine, where the fibres are finally broken down and colouring or mineral loading and sizing are added. This beating is a most important operation, and largely decides the strength, transparency and texture of the finished paper.

The pulp is then transferred to the stuff chests, where it is kept agitated and diluted with about 99 per cent of water in preparation for the paper-making machine. The pulp passes on to the forward-moving supporting wire at the wet end of the fourdrinier paper-making machine, and the water passes through the wire, leaving the fibre tending to lie in the direction of flow.

Just before the pulp loses sufficient water to become self-supporting it passes under, and is locally pressed by, a skeleton brass-wire roller known as the dandy roll. The effect of this local pressure is to increase local translucency and form a watermark. Passage over the couch rolls extracts further moisture, and the paper web is soon sufficiently formed to be self-supporting. Further treatment depends on the results required.

Newsprint, for example, passes over a series of large-diameter drying cylinders which are steam heated in groups to graduated temperatures. There may be 36 cylinders of 4 to 6 ft. diameter. The web also receives some calendering before being slit to required width and reeled. Recent newsprint machines have a wire width of 320 ins. and a production



FOR PAPER-MAKING

into Britain by Henry Fourdrinier (1766-1854), who has given his name to them. Various stages in the process are shown in the above diagram of a typical machine.

speed of 1250 ft. per minute. Book printing, writing and better class papers generally are made on smaller and slower machines with greater elaboration of treatment according to the finish required.

For example, top sizing and calendering may be carried out before reeling; but much treatment may also be given after the initial reeling, such as superior sizing and air-drying, supercalendering (q.v.), plate-glazing (q.v.), friction glazing, coating, maturing and the great variety of finishes given to domestic stationery and novelties.

Reference to the paper-making machine shown in the diagram will indicate (A) the strainers and the pulp-flow control, (B) the endless rubber deckle strap which rides on the wire in the machine direction and returns on pulley supports. This deckle strap forms a retaining wall for the pulp while in its liquid state, and prevents it from running over the edge of the wire while the water runs through the wire, or the extraction is assisted by suction. The endless wire returns on rollers on the underside of the machine as the deckle strap returns on the upper side.

The couch press or couch rolls (C) consist of an upper felt-covered cylinder of twice the diameter of the lower brass- or rubber-covered cylinder. The top cylinder is set back slightly. Pressure between these rolls is adjustable, and their purpose is to extract water from the paper web. The press rolls or wet presses (D) extract still more moisture from the paper as it passes through the rolls supported on the endless woollen wet felts. There may be two or even three banks of press rolls, from which the web passes to the drying cylinders (E).

The drying cylinders will vary in number according to the result required, and they are heated on an increasing temperature scale. (F) indicates the calenders (q.v.) and (G), slitting and reeling.

PAPER SIZES. The sectional growth of the paper-making and using industries has resulted in much lack of co-ordination in relation to terms and sizes. Happily this state is now becoming subject to a greater degree of order and trade agreements, with the result that paper names (e.g., Demy) are now related to definite dimensions in inches.

With the exception of a small but important section of handmade paper which is produced in sheets, paper is made on machines in long webs and then either reeled or cut to the sizes required. The sizes of printing papers are in many cases different from those of writing papers and the following lists are accepted standard sizes. These may be "Double" by doubling the smaller dimensions (e.g., Double Crown—20 in. × 30 in.) or "Quad" by doubling both the dimensions (e.g., Quad Crown—30 in. × 40 in.).

PRINTING.		
Crown	.. 15 in.	× 20 in.
Demy	.. 17½ „	× 22½ „
Medium	.. 18 „	× 23 „
Royal	.. 20 „	× 25 „
WRITING AND LEDGER.		
Foolscap	.. 13½ „	× 17 „
Foolscap and 1/3	.. 13½ „	× 22½ „
Foolscap and ½	.. 13½ „	× 25½ „
Pinched Post	14½ „	× 18½ „
Post	.. 15¼ „	× 19 „
Large Post	.. 16½ „	× 21 „
Ledger Demy	15½ „	× 20 „
Medium	.. 18 „	× 23 „
Ledger Royal	19 „	× 24 „
Super Royal	.. 19 „	× 27 „
Imperial	.. 22 „	× 30 „

A ream consists of 500 sheets or 20 quires of 25 sheets.

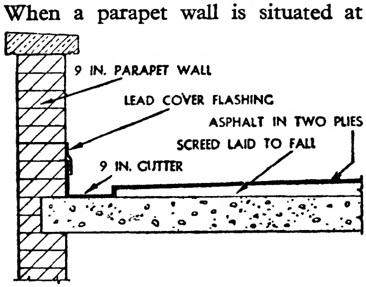
PARAFFIN, see FUELS.

PARALLEL. A method of connecting electrical circuits so that two or more paths are provided for the current. Generators and transformers are connected in parallel when they share a common load.

PARAMAGNETIC. The quality of a substance whose magnetic permeability (q.v.) is greater than unity.

PARAMETERS, see FILTER (Radio).

PARAPET WALL. A wall which projects above a roof surface, or a dwarf wall surmounting a cornice. When a parapet wall is situated at



Section through parapet wall showing general constructional details.

the base of a pitched roof, a gutter is formed behind the wall to assist in the discharge of the rainwater. The gutter is termed a *parapet gutter*, and can be either parallel or tapered. Parapet walls are terminated by a capping member known as a *coping* (q.v.).

PARAPHASE. In valve amplifiers, a method of applying signals to the grids of two valves in push-pull by employing resistance-capacitance coupling in place of a phase-splitting transformer. One of the push-pull valves is fed directly from the previous stage and the other is supplied through a phase-reversing valve, the grids thus being operated with the required 180 deg. phase-difference.

Another system, not strictly paraphase and often called "phase-splitting", uses a valve which feeds one grid of the push-pull pair from its anode and the other from its cathode circuit. Both these arrangements overcome some of the disadvantages of using a transformer.

PARASITE DRAG. The total drag of an aeroplane comes from two sources: there is the induced drag (q.v.) which is incurred in maintaining it in the air, while the remainder, and much the larger proportion, is the parasite drag.

As its name suggests, it is not the result of any useful work, but is due to the skin friction and form drag of the various parts of the aeroplane, such as wing, fuselage etc., and interference drag due to the flow of air being more disturbed over, say, a wing and fuselage combination, than over these parts when separated. The term is sometimes used with reference to drag of all parts except the wings, i.e. total drag less profile drag of the wings and induced drag.

PARASITIC OSCILLATION. Undesirable oscillation in a radio valve circuit usually occurring at very high frequency. Caused by feed-back, it arises at frequencies determined by the small "stray" capacities and inductances rather than by the major characteristics of the circuit.

PARGETTING. The process of rendering the inside of flues with lime mortar. The process is carried out as the flues are built and is compulsory under most building by-laws, unless the flues are lined with square or

cylindrical fireclay tubes. Where the brickwork of the chimney breast passes through a roof or floor or behind any woodwork it should be rendered in mortar if the walls are less than 9 in. thick. See RENDERING.

PARING CHISEL, see CHISEL.

PARIS BLUE, see PRUSSIAN BLUE.

PARKERIZING. In metallurgy, the process of coating ferrous parts by immersing them in a boiling solution of an acid-metal phosphate such as manganese-dihydrogen phosphate. The process, which is a proprietary one (B.P. 270679 etc.), produces a grey coating of insoluble metal phosphates, which considerably improves the resistance of the metal to rusting, on the iron or steel in half an hour to an hour.

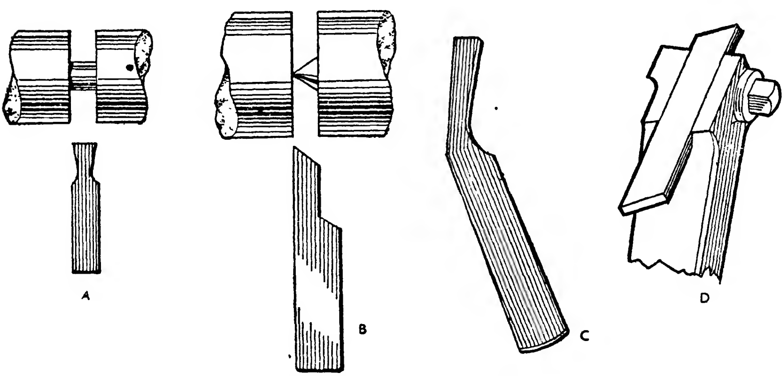
The value of Parkerizing is, however, considerably enhanced if the phosphate coating is impregnated with a suitable oil or lacquer. The usual practice is, therefore, to immerse the phosphate-coated parts in a solution of a black dye (to improve their appearance), and to follow this by impregnation with hot linseed oil. Surplus oil can be removed by centrifuging. Alternatively, a shellac lacquer of a suitable type can be used in the place of linseed oil.

Parkerizing is a development of the Coslettizing process. See COSLETTIZING.

PARTING SAND. Sharp sand used in foundry work for the purpose of preventing two surfaces of a mould from uniting. For example, the top face of the drag is given a light sprinkling before ramming the cope. This ensures a clean lift. Alternatively, sheets of paper may be employed.

PARTING TOOLS. In lathe work, especially, tools for cutting the completed article from the bar out of which it was turned. There are different forms for various types of cut, the most common being shown at A in the diagram. If the blade length is less than the radius of the workpiece, it will leave a small cylindrical "pip" which will afterwards require removal.

By grinding the tool as shown at B a clean facing action can be secured. Parting tools are sometimes bent or offset as in C. A useful arrangement is that shown at D, as the form of toolholder allows the operator to set the tool so that only the very minimum length needed for the cutting-off process projects beyond the tool holder; this largely reduces the tendency of the tool or work (or both) to spring and so cause chattering—i.e. rapid vibration—which is one of the difficulties experienced in cutting-off.



USE OF PARTING TOOLS

Types of tool used in lathe work for severing the finished article from the bar out of which it has been turned, various shapes being available according to the nature of cut to be made. On the right in the illustration is a cutter holder.

The tool should always be set on the horizontal centre line of the workpiece, since if set much lower it tends to dig in. For steel, plenty of oil or cutting compound should be used. The workpiece should be held in a chuck during cutting-off. On no account should the tool be used to cut into two a workpiece held between centres in headstock and tailstock, as the attempt will probably cause the work to bend about the reduced diameter, and so will result in the fracture of the tool.

PARTITION WALL. A wall dividing one room from another and not intended as a load-bearing wall. It may be built of timber, brick, special tiles, or slabs. Partition walls are usually built up from the floor slabs, but when a timber partition wall is to have no support from the floor below, it is necessary to form a truss partition, so that the weight of the wall is transferred to the supports.

PARTY WALL. A wall, forming part of a building, which separates adjoining buildings, constructed, or adapted, to be occupied by different persons.

PASTE. The adhesive used for the application of paperhangings (q.v.), normally made from household flour but, for the application of white papers, sometimes made from white starch. It may be rendered flexible by the addition of a little glycerine. Flours made from other cereals may also be used.

PASTE DRIER, see DRIERS (Painting).

PATTERN. A modified replica of a casting used to shape the mould. In foundry work, most patterns are made from wood, but metal, being more durable, may be used for repetition work, especially in plate moulding.

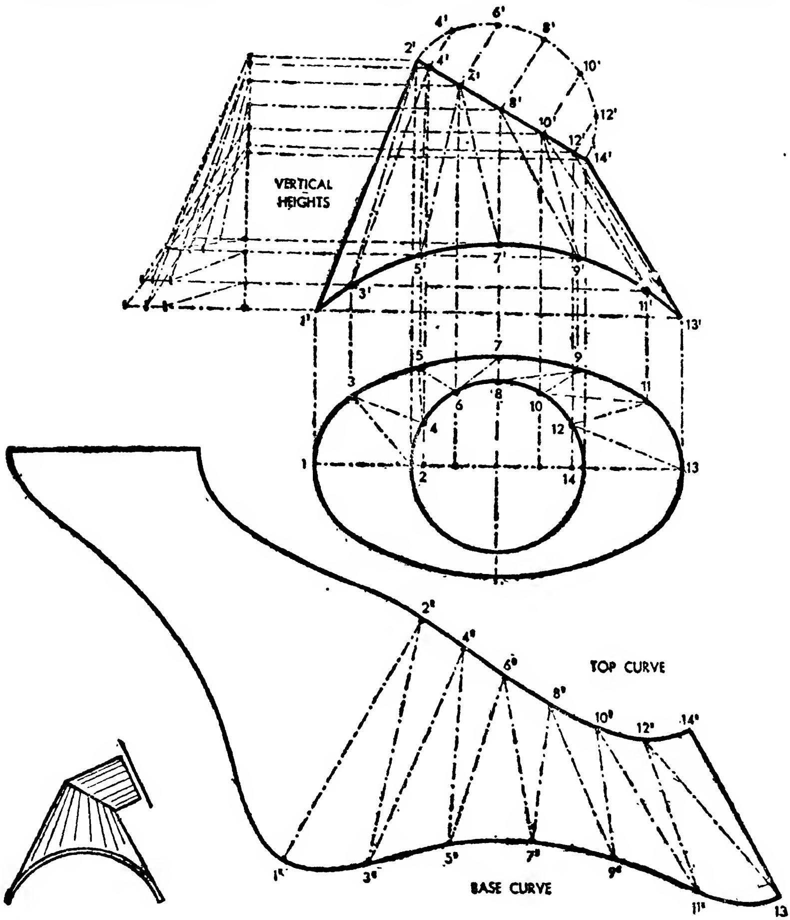
To economize in wood, large patterns are sometimes made in skeleton form, the spaces being filled with plaster or loam. Although the pattern resembles the casting in general shape, it is never identical. It must always be made slightly larger to allow for contraction of the metal in cooling. This allowance for contraction varies with different metals. Thus, if the same casting is required in two different metals, different patterns may be required (see CONTRACTION of CASTINGS).

To facilitate moulding, patterns are often split where joints are to be made in the mould. Metal dowels are generally used to hold the parts together and should be arranged so that reversal of one half of the pattern is impossible. Extra joints in the pattern, if required for only small projections which could not otherwise be drawn from the mould, are avoided by the provision of loose pieces (see LOOSE PIECES). The most important difference between a pattern and a casting, is in the provision of core prints. These are projections on the pattern which form registers in the mould into which the cores fit.

PATTERN DEVELOPMENT. A process of laying-out or unfolding the surface of an object so that the surface lies in a flat plane. The shape of the surface thus developed constitutes the pattern as shown in the illustration opposite. There are three methods in general use by which the pattern for an article may be developed: those of radial lines, of parallel lines and of triangulation.

For an article which has to be made of sheet metal it is generally necessary to develop the pattern. Most articles of sheet metal are hollow bodies in which the thickness of the metal is often small compared to the bulk or size of the article. The shape of the developed surface is then taken as the true pattern without regard to the thickness of metal, and the method of development, as in those mentioned above, depends on a process of practical geometry.

When finished dimensions are required to be accurate, however, the thickness of metal has to be taken into account, and the measurements of the pattern are then obtained by calculation. The relative merits of the methods employed for developing patterns must depend largely on the degree of accuracy required. Approxi-



PATTERNS FOR MOULDING AND CASTING

Patterns are usually made of objects to be formed from sheet metal or by casting. Such patterns result from laying-out the surfaces of the object in one plane.

mate methods are used to obtain the pattern when exact measurements are not important.

PAVEMENT LIGHTS. A panel or frame fitted with small squares or disks of thick glass, so shaped on the underside that a diffused light is transmitted in a downward direction. The glass units in pavement lights are housed in metal or reinforced concrete frames, and are fixed at pavement level or as part of a flat roof. Pavement lights are used where light rays are desired in basement rooms, and where direct lighting through windows is unobtainable. Where it is desired to direct the light rays obliquely, prismatic glasses or lenses are used. These collect the rays and spread them in the desired direction.

PAYLOAD. That part of the load an aeroplane can carry which remains after allowance has been made for the crew, fuel and oil, and any removable equipment not included in

assessing the tare, or empty weight.

P.D. Abbreviation for potential difference (q.v.).

PEAK FACTOR. The peak value of an alternating electrical quantity divided by its root-mean-square value. If the quantity is sinusoidal the ratio is $\sqrt{2}$ or 1·414. See ALTERNATING CURRENT.

PEAK VALUE. The maximum instantaneous value of an alternating electrical quantity. See ALTERNATING CURRENT.

PEARLITE. The eutectoid of iron and iron carbide, so called because, when viewed under the microscope by incident light, it resembles mother-of-pearl. It consists of alternate lamellæ of iron and cementite, the whole containing 0·87 per cent carbon. The mechanical properties of this substance in the normalized state are ultimate stress 56 tons per sq. in. and elongation 10 per cent.

PEDIMENT. An ornament of wood, stone, plaster or concrete, usually triangular or segmental, consisting of a recessed flat field surrounded by a cornice; it is placed over doors or porches of buildings.

PELTIER EFFECT. A phenomenon which causes heat to be absorbed or produced when an electric current passes through the junction of dissimilar conductors.

PENETRATION (Mētallurgy). The depth of metal made molten when metals are welded by the arc process, the parent material being melted by the arc. Penetration depends largely on the arc voltage, and to a lesser extent on the current flow, electrode size and the material being welded. With the higher-arc voltages now coming into use and consequent greater penetration, larger plate sections may now be welded without any preliminary preparation.

PENTAGRID. Another term for heptode (q.v.), a radio valve having seven electrodes, that is, five grids in addition to cathode and anode. Its chief use is as a frequency changer.

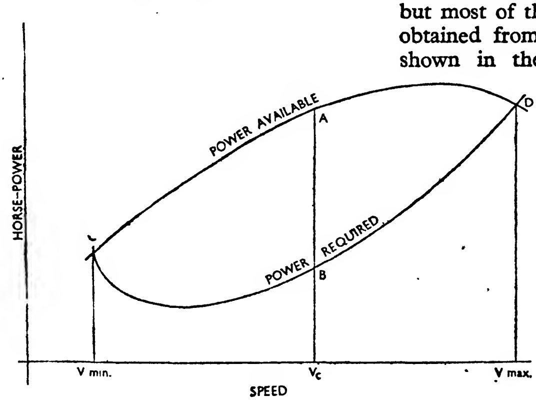
PENTAVALENT, see VALENCY.

PENTODE. A five-electrode radio valve, comprising cathode, anode and three grids. See RADIO VALVE.

PEPPERMINT, see EUCALYPTUS.

PERFORMANCE (Engineering). The operating characteristics of a mechanism or apparatus. Performance in aeronautical engineering, for example, embraces the many flying characteristics of an aircraft, e.g. cruising and maximum speeds and the corresponding altitudes, stalling speed, rate of climb, service and absolute ceilings, range, payload and fuel loading etc.

These data are always given for a theoretical standard atmosphere (q.v.), which represents average conditions, so that comparisons may be made. They are usually given numerically, but most of the data may be readily obtained from Performance Curves, shown in the accompanying illustration. The upper curve gives the power available throughout the speed range, and the lower one that required to overcome drag. The vertical distance between them at any point gives the power available for climbing, from which the rate of climb may be calculated. The speed V_C, for which the longest vertical line,



Performance curves from which some of the flying characteristics of an aircraft may be calculated.

AB, can be drawn between the curves, is that for maximum rate of climb. The cutting points of the curves, C and D, give the minimum and maximum speeds for level flight, v_{min} and v_{max}, respectively.

The power required changes with altitude, and a family of curves for a range of altitudes may be drawn, from which the above data may be obtained for each altitude. Similarly, the power required varies with the load, and a family of curves may be drawn for different loaded weights, and the corresponding data obtained.

PERIOD. The time required for the completion of one cycle, that is, the recurrence of similar characteristics, in a varying quantity. For a frequency of 50 cycles per second the period is 0·02 seconds. See ALTERNATING CURRENT.

PERIODIC. The quality of changes in electrical or other quantities which repeat themselves at regular intervals. For example, the motion of a clock pendulum. See ALTERNATING CURRENT.

PERIODIC TABLE OF THE ELEMENTS. It is possible to arrange all the elements in a table that shows a number of groups or families, each of which includes elements with rather similar properties.

The first attempt to make such a table was made in 1864 when Newlands arranged the elements in the order of their atomic weights, and showed that they fall roughly into groups of eight elements each. This he called the Law of Octaves, but it did not find favour with the chemists.

The general principles of this arrangement were adapted, extended and improved by Mendeliev about 1870 to give the tabulation now adopted, upon which is based the accompanying table. This sets out the elements in numerical order, and the nine main horizontal divisions include elements with some chemical resemblances, except the last one, which includes the rare gases with no valency that do not in any way resemble the elements iron, palladium and platinum, Thus, in the first division lithium, sodium, potassium, rubidium and caesium are very similar to each other; so are copper, silver and gold. All the elements in each division resemble each other chemically.

PERITECTIC REACTION. A reaction between two phases, during the solidification of a binary alloy,

GROUPING OF ELEMENTS

Groups	Atomic Numbers						
	1–2	3–10	11–18	19–36	37–54	55–86	87–92
I	Hydrogen	Lithium	Sodium	Potassium Copper	Rubidium Silver	Caesium Gold	
II		Beryllium	Magnesium	Calcium Zinc	Strontium Cadmium	Barium Mercury	Radium
III		Boron	Aluminium	Scandium Gallium	Yttrium Indium	Lanthanum & 13 rare Earths Thallium	Actinium
IV		Carbon	Silicon	Titanium Germanium	Zirconium Tin	Hafnium Lead	Thorium
V		Nitrogen	Phosphorus	Vanadium Arsenic	Niobium Antimony	Tantalum Bismuth	Protoactinium
VI		Oxygen	Sulphur	Chromium Selenium	Molybdenum Tellurium	Tungsten Polonium	Uranium
VII		Fluorine	Chlorine	Manganese Bromine	Masurium Iodine	Rhenium	Plutonium
VIII				Iron Cobalt Nickel	Ruthenium Rhodium Palladium	Osmium Iridium Platinum	
O	Helium	Neon	Argon	Krypton	Xenon	Radon	

resulting in the production of third phase. Such a reaction occurs at a fixed temperature. A typical example is given by the copper-tin alloys. See EQUILIBRIUM DIAGRAM—PERITECTIC TYPE.

PERMALLOY. An alloy of nickel and iron which has greater magnetic permeability and less hysteresis loss than ordinary soft iron when the magnetizing force is fairly low. See MAGNETIC HYSTERESIS and PERMEABILITY.

PERMANENT MAGNET. A magnet which requires no electrical excitation after its initial magnetization. Older materials were alloys of iron and chromium, tungsten, or cobalt, but newer materials such as "Alnico" greatly increase the performance which may be obtained from unit volume of material. This is due to increased coercive force (q.v.).

Permanent magnets are used on all types of magneto in order to produce the magnetic field which acts upon the windings to produce an e.m.f. These are of alloy metals and are very powerful. The magnetic effects of a magnet can be partially or wholly destroyed by sudden shock or heating. A magnet has two poles which are strongest near its extremities, termed the north-seeking pole and south-seeking pole respectively. See MAGNET and MAGNETO.

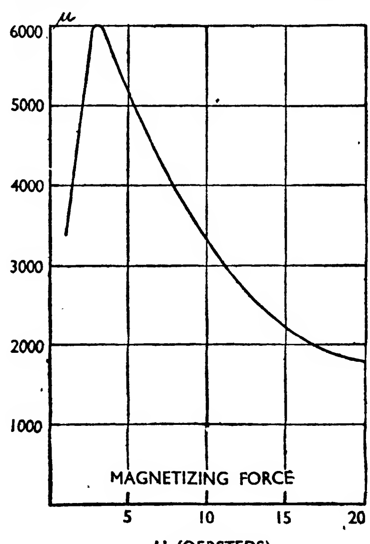
PERMEABILITY. Symbol: μ. The magnetic flux-density produced in a material, divided by the flux-density produced in air by the same magnetizing force. The relation may be expressed as: flux-density (B) equals permeability (μ) multiplied by magnetizing force (H). For air and other non-magnetic materials the permeability is unity. For magnetic materials it varies quite widely with the magnetizing force. This is illustrated in the diagram. See MAGNETIC FLUX-DENSITY and MAGNETIZING FORCE.

PERMEABILITY TUNING. A method of tuning a radio circuit by altering its inductance by means of a movable iron core.

PERMITTIVITY. Symbol κ. The electric flux-density produced in a material, divided by the flux-density produced in air by the same electric force. The permittivity of porcelain is about 5, of glass about 7 and of paper about 2½, but all vary with composition and treatment. Synonyms: dielectric constant (q.v.) and specific inductive capacity.

PETERSEN COIL. A protective reactor (q.v.) for overhead electric lines, normally connected between the neutral point and earth. Matters are so arranged that under fault conditions the current taken by the coil balances the capacitance current from lines to earth.

PETROL. The name used in Britain for the fraction of petroleum suitable for use in internal-combustion engines such as those fitted to road vehicles. Crude petroleum is obtained in many parts of the world by drilling; it is a mixture of many different hydrocarbons, i.e., compounds of hydrogen and carbon. The crude petroleum is treated so as to yield products needed for a specific purpose, and the chief processes in a very complicated treat-



Graph showing how permeability of iron and similar materials varies with magnetizing force. For non-magnetic materials, permeability is constant.

ment are distillation, chemical refining and cracking.

The distillation separates the lower-boiling constituents from the higher-boiling ones; the chemical refining removes objectionable constituents, and the cracking converts some of the higher-boiling constituents into lower-boiling ones. The distillation takes place in complicated stills; the chemical refining makes use of sulphuric acid, caustic soda, litharge dissolved in caustic soda, and other substances. Cracking is a process of heating the higher-boiling constituents under pressure and converting the most complicated components of the mixture into simpler ones.

The crude petroleum is usually a mixture of paraffin, naphthenic compounds and asphaltic bitumens. The paraffins are hydrocarbons of the general formula C_nH_{2n+2}, and the principal ones in petroleum are the pentanes, hexanes, heptanes, octanes and nonanes, with 5, 6, 7, 8 and 9 carbon atoms respectively. There are very many different nonanes and octanes, and the same applies to the other paraffins above mentioned. The naphthenic compounds are hydrocarbons with the general formula C_nH_{2n}, in which some of the carbon atoms form two rings, each containing six carbon atoms; these naphthenic compounds are valuable because many of them have anti-knock properties. The asphaltic bitumens are thick liquids, often dark coloured, or dark-coloured solids; by suitable treatment they may be partially converted into naphthenic compounds.

Aviation spirit is the fraction of petroleum suitable for aeroplanes, and it consists mainly of hydrocarbons boiling between about 35 and 150 deg. C. One of the most useful of these is iso-octane, which boils at about 117·3 deg. C.; it has very good anti-knock properties, and the so-called octane number is in this respect a measure of the quality of aviation spirit. The octane number (q.v.) of a sample of such spirit is in theory the percentage of iso-octane in a mixture of that liquid and heptane that gives the same properties or results as the sample. See FUELS.

PETROL PUMP, see FUEL PUMP.

pH. An expression used to record comparative alkalinity and acidity. It represents the logarithm of the reciprocal of the hydrogen ion concentration in a solution.

Pure water is very slightly ionised as follows:—

$$H_2O = H^+ + OH^-$$

The extent of this ionization is such that 10^{-7} gram equivalents per litre of hydrogen ions are present in the pure water. Similarly, the same amount of hydroxyl ions is present, the water being neutral. An increase in the hydrogen ion concentration will mean that there is an excess of these ions over the hydroxyl ions, and such a solution is acid.

Correspondingly, if the hydroxyl ions are in excess of the hydrogen ions, the solution is alkaline. The product of the hydrogen ion concentration and the hydroxyl ion concentration is always 10^{-14} gram equivalents per litre in any solution.

For convenience, the index only is considered and the negative value of this is the pH. Thus a pH value of 7 means that the hydrogen ion concentration is 10^{-7} gram equivalents per litre, and this will also be the concentration of hydroxyl ions. Such a solution will be neutral. pH values from 7 down to 0 are acid values, and from 7 up to 14, alkaline.

It will be noted that a fall or rise of 1 in pH value represents a change in hydrogen or hydroxyl ion concentration of 10 times the previous value.

PHANTOM CIRCUIT. An electrical circuit obtained by using two pairs of lines, the constituent members of the pairs being in parallel, in such a way that currents in the phantom circuit cancel out in each separate pair.

PHANTOM LOAD. An arrangement of electrical circuits whereby current and voltage are separately supplied. This produces the effect of a load, for example in a wattmeter, without the necessity of supplying power, other than to replace losses.

PHASE (Elec. Engineering). A single electrical line or circuit of a multiphase system. The term is also used to indicate the relative positions of vectors or the relations between the quantities they represent. See ALTERNATING CURRENT.

PHASE. In metallurgy, a term denoting a physically distinct substance, homogeneous throughout. A phase is not necessarily of fixed composition, but may show some variation, without, however, any sudden change in the physical properties. In binary alloys, a maximum of three phases is possible if the vapour phase is neglected. They may consist of pure metals, liquid or solid solutions, or inter-metallic compounds.

PHASE ADVANCER. An electrical device for increasing the power factor of an induction motor. It normally does this by injecting an e.m.f. into the winding which is not connected to the supply.

PHASE DIFFERENCE. Symbol: ϕ. The relation between two electrical quantities, which have the same frequency, usually expressed as the angle between the vectors by which they are represented (see ALTERNATING CURRENT). The term is also used to express the angle by which the output current or voltage of a current or voltage transformer fails to be in exact opposition to the input current or voltage. See INSTRUMENT TRANSFORMER.

PHASE DISTORTION, see DISTORTION.

PHASE MODULATION, see MODULATION.

PHASE SEQUENCE. The order in which a related set of electrical vectors reach their maximum (or any other) value. See ALTERNATING CURRENT.

PHASE SPLITTING, see PARAPHASE.

PHENOL, see BENZENE and COAL.

PHOSPHOR, see CATHODE-RAY TUBE.

PHOSPHOR BRONZE. A copper-tin-phosphorus alloy. The commercial casting alloys contain 8 to 20 per cent of tin and up to 1·5 per cent of phosphorus. Phosphorus is a hardening agent and exists in the metal as globules of copper phosphide Cu_3P, associated with the δ constituent normally present in bronzes. The presence of phosphorus in appreciable amounts vastly improves the bearing qualities of the alloy, but the ductility is small compared with that of gunmetal (q.v.). The cast alloys are much used for such duties as gear-wheels (especially worm wheels) and bearing bushes.

Wrought phosphor bronzes containing 3 to 8 per cent of tin and 0·1 to 0·25 per cent of phosphorus are available in the form of sheet, strip, wire, tube etc. Cold-rolling increases very considerably the strength and hardness of the alloys in this range of composition. In this form they are used for electrical switchgear components, where springiness, combined with good electrical conductivity and resistance to corrosion, is required.

PHOSPHORUS (P). Atomic no. 15; atomic wt. 31·02; a non-metallic element that exists in several allotropic varieties, of which the principal are: (1) yellow phosphorus, a waxy solid, with a specific gravity of 1·83, which melts at 44 deg. C. and boils at 287 deg. C.; it is readily soluble in carbon disulphide, easily catches fire on warming, and is very poisonous; (2) red phosphorus, a violet-red, amorphous powder, specific gravity 2·106; on being strongly heated, it is converted into a vapour which condenses to the yellow variety. Red phosphorus does not readily ignite; it is insoluble in carbon disulphide and is not very poisonous.

Phosphorus occurs in nature in many minerals, e.g., apatite, a calcium phosphate and fluoride, $3Ca_3(PO_4)_2.CaF_2$; vivianite, an iron phosphate, $Fe_3(PO_4)_2.8H_2O$, and other phosphates. It occurs in bones as a calcium phosphate and in many other animal tissues; phosphorus compounds are necessary to the growth of all animals and plants. On the large scale, phosphorus is obtained by heating phosphates with sand and coke in an

electric furnace, distilling off the phosphorus and condensing it under water in the yellow state. The red variety, used largely in the match industry, is made by heating the yellow phosphorus to 240 deg. C. in an iron pot and subsequently boiling with a solution of caustic soda.

Phosphorus is trivalent or pentavalent, forming hydrides, PH_3 and P_2H_4, and oxides, P_4O_6, P_2O_4 and P_4O_{10}. A sulphide, P_4S_3, is largely used in the manufacture of safety matches. Phosphorus pentoxide, P_4O_{10}, readily combines with water to form metaphosphoric acid, HPO_3, which may be converted into pyrophosphoric acid, $H_4P_2O_7$, and orthophosphoric acid, H_3PO_4. From these acids a number of phosphates are prepared, one of which, sodium phosphate, $Na_2HPO_4.12H_2O$, is used on a commercial scale.

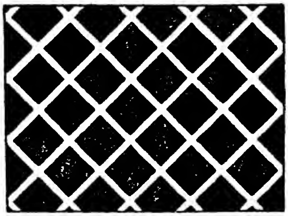
If insoluble calcium phosphate, a fairly plentiful mineral, $Ca_3(PO_4)_2$, is treated with sulphuric acid, a soluble phosphate, known as "superphosphate", is obtained. This has the formula $Ca(H_2PO_4)_2$, and is used in very large quantities as a fertilizer. It usually contains a proportion of calcium sulphate.

PHOTO-ELECTRIC CELL. A device whose electrical characteristics depend upon the amount of light falling on it.

Thus, in the photo-conductive cell the resistance changes when light falls upon the cell, and in this manner effects changes in the electrical current passing through it, whereas in the photo-emissive cell emission of electrons takes place under the influence of light and a current is produced which varies with variations in the intensity of the light. Such cells are used in photographic exposure meters and in instruments for measuring illumination. In a third type, the photo-voltaic cell, a potential difference is produced by the light falling upon it.

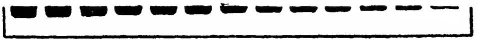
PHOTO-ELECTRIC EFFECT. A change in electrical characteristics produced by light. See PHOTO-ELECTRIC CELL.

PHOTOGRAVURE. A photomechanical method belonging to the intaglio group of printing processes (see PRINTING). Depth of tone with smooth, almost photographic gradation and velvet-like finish are features of this process. The screen is not obvious in pictorial production, but intrudes on type matter, causing loss of fine definition. In earlier productions, a natural grain was produced on flat copper plates. Hand control was largely used in printing, but superfine results were obtained on short runs; this method still has a limited use.



(a)

(b)



(c)

Section of photogravure screen (a); plate after etching (b) showing depth of cells and (c) cells containing ink.

Modern practice employs rotary machines in which the formes may be either steel cylinders, on which a face of copper is electro-chemically deposited, or flexible copper plates which are clamped round a steel cylinder on the printing press. Pictorial reproduction requires a continuous-tone positive photographic plate, and this is usually made in the camera from a retouched negative. Carbon tissue (q.v.) is then made sensitive to light by immersion in potassium bichromate solution in water, dried and exposed to the screen, shown in the illustration.

A normal photogravure screen has 150 or 175 lines to the inch, but finer screens are often used for type reproduction. The effect of this exposure is to produce a cross-line effect on the tissue, which divides the printing image into small cells. The walls of this cell formation support the doctor blade and prevent it from removing ink from the image recesses; they also maintain tonal values by controlling the quantity and distribution of the printing ink.

The carbon tissue is then exposed to the continuous-tone positive. The gelatin hardens from the surface to a depth which is decided by the amount of light acting upon it. The gelatin resist is therefore of varying hardness, but hardest in the sections corresponding to the highlights of the positive.

The tissue is then moistened, squeezed into position on the copper plate or cylinder and developed in warm water. This removes the backing paper, washes away the unhardened resist and leaves a varying thickness of resist depending upon the degree of light-hardening. The surface is dried, the parts which are to remain clear are stopped-out with an acid-resisting varnish, and the surface is ready for etching with a mordant of ferric chloride dissolved in water.

About five strengths of etching solution are used, the strongest being of a density between 41 and 43 deg. Baumé, and the rest decreasing in stages of 2 deg. As the first etch is applied, it attacks the thinnest film and penetrates to the metal. This strength of etch would continue to attack the metal, but not to penetrate more gelatin, and change is made to an etch of lower density. Once the metal is reached, the etching continues whatever strength etch is used, but progressive penetrations of the resist require progressive reduction in mordant density.

The surface of the plate or cylinder is cleaned and is then ready for printing. The deepest recesses have a depth of about $\frac{2}{1000}$ in. and the rest are correspondingly shallower and, therefore, carry less ink. Reference to the screen shown at (a) in the diagram will indicate the square and uniform shape of the cells, whilst at (b) is shown a diagrammatic section of the various cell capacities together with the doctor-blade supports formed by the cell walls. The different capacities of the inked cells are shown at (c). In practice so much ink is carried by the deepest cells that, in the print, the individual cells lose their identity as the ink runs together into a solid.

Machine Design

Gravure machines have a range similar in type and speed to letterpress machines, but they are extremely simple in design and consist essentially of a forme cylinder, which either runs in an ink fountain, or is supplied by a single inking roller partly immersed in the fluid ink in the fountain. A flexible-steel doctor-blade removes ink from the surface of the forme, leaving the recesses charged, and the print is taken by direct contact of paper with the inked image. Heavy pressure is applied between paper and image by the impression cylinder, which is covered with a fairly hard vulcanized rubber-deposited canvas sheet similar to an offset blanket. The ink used is very fluid and volatile, so that the printed sheets are practically dry as they leave the machine.

Sheet-fed machines run within the range of the automatic feeder, while newspaper-web units find approximately 11,000/16,000 per hour an economical and practical speed. In modern practice in which enclosed ink fountains are used, recovery of the volatile solvent is an important feature. Work of an attractive type is done in full colour on these high-speed machines, and with an economy in the number of printings which is unequalled by any other printing process. Very effective results can be obtained in two printings.

The term gravure has many prefixes but the principle is the same. Either these terms are self-explanatory or they are trade names. Examples are: rotary photo-, roto-, rota Alco-, colour-,

collo-, Sun- and so on. Marked advantages of this process include high printing speeds, little or no make-ready, quick drying of the print, little trouble with set-off, and the ability to use low-priced paper.

PHOTOLITHOGRAPHY. A method of printing which utilizes the camera to produce a photographic image from which the lithographic printing image is made. The photographic image may be in line or half-tone, but not in continuous tone. Either negative or positive images can be used according to the method of treatment, and these may be on paper, film or glass with certain restrictions.

The lithographic plate, which is usually of zinc or aluminium, is grained and counter-etched with a dilute-acid solution. The plate is then coated with a colloidal film, such as albumen or casein, which is made light-sensitive with ammonium dichromate solution. When this film is dry, the photographic plate is placed in contact with the prepared litho plate and subjected to an intense light which is rich in ultra violet rays.

The result of this is to harden the parts of the film which have been exposed to light through the transparent sections of the photographic plate, and cause them to be insoluble in water. The sections which are preserved from the light by the opaque parts of the photographic plate—or otherwise—remain water soluble. A thin coating of waterproof ink is distributed over the plate, which is then developed with water to remove the unhardened deposit, thus leaving the inked image visible and requiring simple treatment in preparation for the printing machine.

A large and varied amount of work is done by this method, from simple stationery headings in one colour to faithful reproductions of art works, and from small labels to posters. An increasing application is in the reprinting of books.

PHOTOMETER. An instrument for measuring illumination, luminous intensity etc. The measurement is usually, but not necessarily, made by comparing the unknown with a standard such as a standard lamp having a known candle-power.

PHUGOID OSCILLATION, see LONGITUDINAL STABILITY.

PICKLING. The process of removing scale or oxide from the surface of a metal, such as iron or steel. Two methods are in general use, incorporating immersion respectively in hydrochloric acid and in sulphuric acid.

HYDROCHLORIC ACID: The strong commercial hydrochloric acid contains about 30 per cent of gaseous HCl dissolved in water; it is sometimes used in this form but is more generally diluted. The solution is used cold, on account of the volatility of the acid.

The pickling action is a dual one; in part the acid dissolves the oxide, whilst a simultaneous attack proceeds on the underlying metal at its junction with the scale particles, so that the latter are loosened and fall away. To minimize attack on the metal, it is common practice to add a pickling "inhibitor" (usually an organic colloid) which forms a protective film over the descaled areas, thus conserving metal and acid.

Hydrochloric acid is a more expensive pickling acid to use than sulphuric. but as it dissolves oxides rather better than the latter, it is useful where rust is present in addition to scale. It is mainly employed for the pickling of iron and steel before tinning, galvanizing, electro-plating etc., either alone or following a sulphuric-acid pickle.

SULPHURIC ACID: The rate of attack of sulphuric acid on the metal is very slow when it is used in the concentrated form, so that it is employed at a dilution of 5 to 20 per cent. The best results are obtained when the acid is kept heated at a temperature of 120 deg. F. to 160 deg. F., and preferably agitated by stirrers or by compressed air. The pickling action is largely mechanical; the gas bubbles produced by the action of the acid on the metal beneath the scale particles loosen the scale so that it becomes detached and falls to the bottom of the tank. As mentioned above, inhibitors are often used to

minimize attack on the descaled areas of metal.

As metallic salts accumulate in the acid the action of the latter becomes slower; the temperature can then be raised to speed-up pickling, but when a concentration of about 6 per cent of sulphates builds up in the solution it is generally uneconomic to add fresh acid, and the pickle should be discarded.

Sulphuric acid is successfully employed for the pickling of brass and copper as well as of ferrous metals. Tanks for sulphuric-acid pickling are usually made either of lead-lined wood or of special acid-resisting brick.

PICK-UP. See GRAMOPHONE PICK-UP.

PIECE MOULD. A mould made up of a number of pieces that fit into each other. The various pieces can be removed separately in cases where the moulded object is of such a shape that it could not otherwise be withdrawn.

PIERCING, see POWER PRESS AND PUNCHING MACHINE.

PIER FOUNDATIONS. The loads of a skeleton-framed structure may be transmitted to the soil as point loads through the medium of a brick pier. The superficial area of the concrete base required to support the concentrated loads transmitted from the pier should be obtained by calculation, dividing the total load on the concrete base by the safe permissible load on the soil.

If the soil is such that a large superficial area is required, it is the usual practice to insert steel reinforcement bars in the concrete base to counteract tension in bending. As the concrete base may be considered as an inverted cantilever on each side of the pier, and uniformly loaded by the upward reaction of the soil and supported by the pier, the reinforcement should be placed as near as possible to the bottom of the base.

PIEZO-ELECTRIC. A term meaning *pressure-electric* and applied to a property peculiar to certain crystals. If a slice of quartz or Rochelle salt be mechanically compressed, its opposite faces exhibit a potential difference and conversely, if a voltage be applied to its opposite faces, its physical dimensions change.

This effect is said to be piezo-electric and is employed in microphones and loudspeakers. When such a slice of crystal is subjected to an alternating potential difference, it oscillates or vibrates mechanically and shows a very strong tendency to do so at one particular frequency. In many respects it behaves like a tuned circuit. See CRYSTALS (Radio) and QUARTZ CRYSTAL.

PIG IRON. A complex alloy of iron with carbon, silicon, sulphur, phosphorus and manganese, produced in the blast furnace. Together with scrap cast-iron and steel it forms the basis of all cupola charges. The properties of castings produced from a given type of pig depend mainly on the proportions of carbon, silicon and phosphorus present.

Carbon can exist in two different forms in cast-iron, either as combined carbon or as free graphite. If the proportion of combined carbon is high the casting will be hard and show a white or mottled fracture. A high proportion of graphite, however, will make the iron soft and the fracture will be grey. The effect of silicon is to promote graphitization, and the state of the carbon can therefore be controlled by the amount of this element permitted in the charge.

Phosphorus imparts great fluidity of the iron, and up to 1·5 per cent may be used for making light, delicate castings. The amount should be restricted to less than 0·6 per cent if high-strength castings are required. Pig irons are of various types as shown in the following table:

TYPE OF PIG	CARBON	SULPHUR	PHOSPHORUS
Haematite	High	Low	Low
Cold blast and Refined Irons	Low	Low	Medium
Phosphoric	Medium	High	Very high

All these irons are available with varying silicon content, so that the

cupola charges may be adjusted to the required figure for this element.

PIGMENTS (Painting). Natural or artificially produced solids used to give substance, opacity and colour to paint. They may be natural earths or chemically produced metallic compounds and dyestuffs of organic origin fixed upon an inorganic base. The ideal pigment is permanent, inert and causes no chemical reaction with the media or with the other pigments with which it may make contact. They may be obtained by painters in the form of dry, soft powder or as stiff pastes ground into water, an emulsion, turpentine or refined linseed oil.

As pigments vary considerably in weight for bulk and also in nature from crystalline to flocculent, the amount of liquid required to make a paste is not consistent; this has to be acknowledged and allowed for when, by the addition of further quantities of media and diluent, they are being converted into a usable paint.

The pigments in general use are: natural earths—whiting (Paris or English white); ochre, sienna, umber; vandyke brown; red oxides of iron; mineral black and graphite. Artificially made chemical compounds are: Whites—white lead, sublimed white lead; zinc oxide, lithopone, antimony oxide, titanium oxide and titanium white. Reds—iron oxides (Venetian red, Indian reds, purple oxides); burnt sienna; red lead, lead chromate and vermilion. Yellows—lead; chromes; zinc chromes and synthetic ochres. Greens—Brunswick greens, lime green and oxide of chromium. Blues—ultramarine blue, Prussian blue and lime blue, a reduced form of ultramarine blue.

Artificial pigments and lakes (q.v.) may be obtained in any colour, the former being dyestuffs fixed upon an opaque base and the latter upon a transparent base. See LITHOPONE, OCHRES, OXIDES, PRUSSIAN BLUE, RED LEAD, SIENNA, ULTRAMARINE, UMBER and VERMILION.

PILE. A long shaft of wood, steel, or concrete, extending down through soft, marshy soil until its end rests upon a solid foundation, or penetrating far enough into the soil to obtain support by frictional resistance for its load.

There are various kinds of pile, which may be of timber, steel or reinforced concrete. In modern construction, the use of timber has almost ceased and piles are now generally made of reinforced concrete. The size and length of precast reinforced-concrete piles are determined by the ease with which they may be handled and transported. There are several methods of casting the pile in position. Piles may be used for the purpose of sheet piling or spaced piling, the object of the former being to assist in retaining the earth under foundation.

PILE FOUNDATION, see FOUNDATION.

PILING, see TEMPORARY TIMBERING.

PILLAR VALVE. A vertical tap in the shape of a pillar secured to the fitment by a long thread and backnut, with the outgo of a length to suit its purpose. The construction is the same as that of a stop cock (q.v.).

PILOT WIRE. A wire, usually run with, or adjacent to, an electrical transmission line or cable, for use with protective gear for testing and measurement purposes, or for communications.

PINE. A coniferous tree yielding valuable timber and found chiefly in the northern parts of Europe, Asia and America. As far as timber is concerned there are two main classes, the hard and the soft pine. Soft pines are easy to work and, in most species, free from knots; hard pines are known as pitch pines, are very resinous and much harder to work, although more durable. See PITCH PINE, TIMBER and WHITE PINE.

PINHOLING AND POCKMARKING. The appearance in the surface of paint of small holes which do not extend through to the ground. It is restricted mainly to varnish and enamel and may be due to the addition of turpentine or white spirit by the operative. Varnish and enamel are made ready for use and

should not be diluted. The execution of the work in a damp, close atmosphere may also cause this fault.

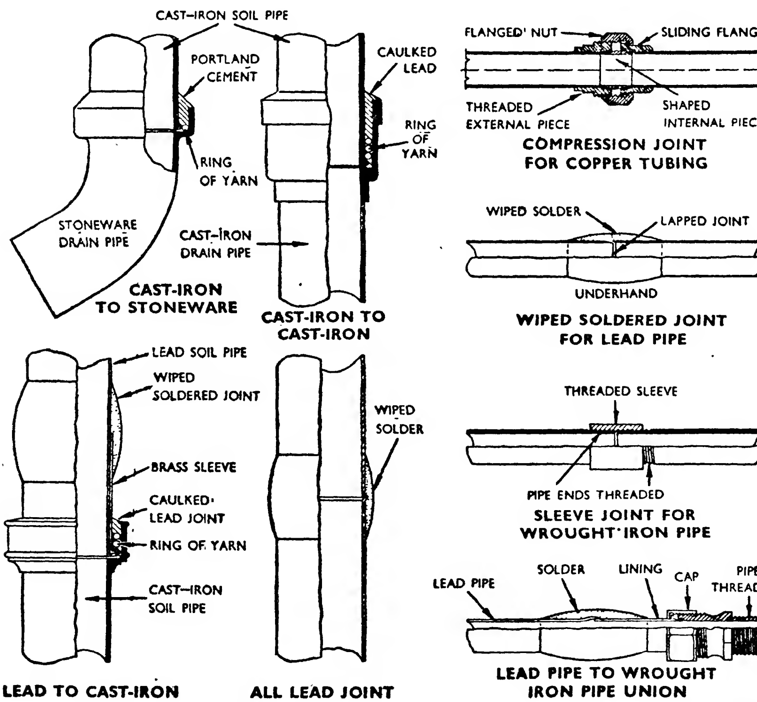
PINION, see GEARBOX.

PINS-AND-LINE. A piece of string, termed a line, attached to two small knife blades, or pins, which are pushed into the mortar joints at each end of a course of brickwork. The line is set so that it is level with the top edge of the course about to be laid and assists in bringing the bricks in that course to the correct vertical and horizontal position. See BOND and CLOSER.

PIPE JOINTING AND FIXING. The jointing and fixing of piping, in either water supply or drainage, depends on the size of the pipe and the material of which it is made. Small-diameter wrought-iron pipes are usually threaded and joined with a threaded sleeve; large-diameter cast-iron pipes are made with spigot and socket ends, joined with yarn or gaskin, and caulked with molten lead, lead wool or rope (see CAULKING).

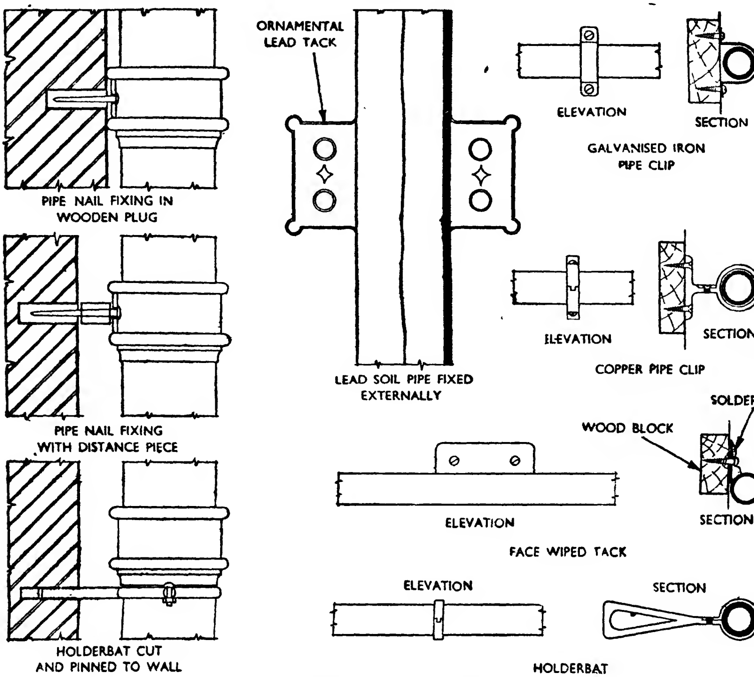
Copper piping can be welded or joined with a compression joint. In this the sliding flange, together with the flanged nut, is slipped over one end of the pipe and the bore expanded to take the shaped internal piece. The threaded flange having been slid on to the section to be joined and the bore similarly expanded, the two are brought together and joined by screwing the flanged nut tightly over the threaded external piece.

Glazed-stoneware pipes are jointed with Portland cement, the space between the spigot and socket being



JOINTINGS FOR PIPES

Fig. 1. Various methods of jointing and fixing drainage and water-supply pipes are used according to the size and nature of the pipe. Above diagram shows appropriate joints for pipes of stoneware, cast-iron, lead, copper and wrought-iron.



FIXINGS FOR PIPES

Fig. 3. Methods of fixing pipes must be chosen according to the nature of the material of which the pipe is made and the surface to which it is to be fixed.

filled with cement and flaunched up on to the pipe. As shown in Fig. 1 a ring of yarn or gaskin is sometimes put in first to prevent the cement being forced through into the pipe. All piping joined in this way should be cleaned out internally afterwards.

Lead pipes are joined with a plumber's wiped-soldered joint, the two ends of the pipe being first lapped or mitred, then soldered with sufficient bulk of metal to withstand the head or pressure.

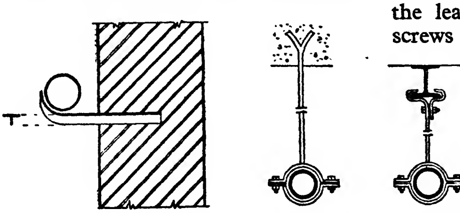


Fig. 2. T-iron bracket supporting cast-iron drain on wall (left); hanging brackets from concrete (centre) and from rolled-steel joist (right).

In cases where pipes of different material have to be joined, such as lead to fireclay, lead to cast-iron etc., a brass sleeve or thimble is used. Fig. 1 shows a lead pipe connected to a wrought-iron pipe by means of a threaded union piece. A specially shaped flanged brass sleeve, together with threaded cap, is first soldered to the lead pipe, after which the cap screws easily over the union. The same illustration shows a brass thimble soldered to a lead pipe and joined by means of cement to the glazed outgo of a W.C. pan. There is also an enlarged view of the soldered connexion of the brass thimble to the lead pipe. Types of joint

for cast-iron to stoneware, lead to stoneware and lead to cast-iron are shown. Asbestos piping is made and joined in the same manner as cast-iron piping, but the jointing materials used are yarn and asbestos cement.

Various devices are employed to fix pipes of different materials to the walls of buildings, internally or externally. Small-diameter lead pipes are fixed mainly by means of sheet or cast-lead tacks, as shown in Fig. 2. The tacks are lead plates, soldered to the pipe, through which pipe nails can be driven into hardwood plugs pinned to the wall.

Also shown in Fig. 2 are pipe clips and a wood fillet on which the pipe can rest. Lead pipes, fixed in chases (channels) left in the wall, can be fastened to the pipe by taft joints and attached to wooden blocks built across the chase or into the wall.

Methods of fixing copper and wrought-iron pipes, mainly by clips pinned or screwed to the wall or to wooden blocks set in the wall, are shown in Fig. 3. Brass holderbats built into the wall and secured round the pipe suit any copper installation, whether welded or compression-jointed. Copper piping can also be secured by copper tacks bronze-welded to the pipe in the same manner as lead piping.

Cast-iron pipe may be obtained with ears for fixing to hard-wood plugs, or without ears for fixing to holderbats. Fig. 3 also shows the method of fixing large-diameter soil pipes. Cast-iron pipes fitted with ears and pipe nails are usually too close to the wall for periodical painting or repairs, but this disadvantage can be overcome by fixing distance pieces behind the ears. Short lengths of $\frac{3}{4}$-in. steam barrel slipped on to the pipe nail will serve the purpose. Asbestos pipe is made without ears and is fixed with holderbats.

PIPE NAILS (Foundry). Forms of chaplet shaped like nails with large heads and used to provide additional support to pipe cores. If fitted with specially large heads shaped to fit the core, they are known as pipe chaplets.

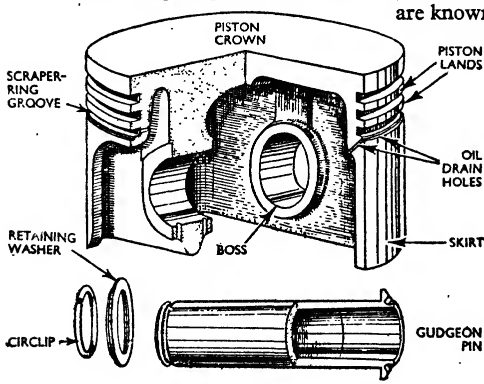
PISTON. A circular disk or plunger which moves to and fro, or reciprocates, in a cylinder (q.v.), against fluid pressure, as in pumps; under steam pressure, as in steam engines; under explosive force, as in internal-combustion engines.

In the latter, shown in the diagram, the force exerted upon the piston by the combustion in the cylinder is transmitted to the crankshaft by means of the connecting rod and is thus made to do useful work by being converted into rotary motion.

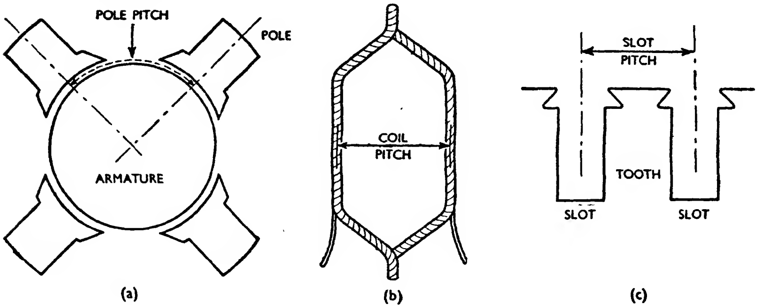
Since reciprocating parts must be as light as possible, the piston is hollow and most modern types are made of light alloys, the metal being thicker at the top, or "crown", of the piston because it is that part which takes the force of combustion, and has to bear the greater part of the heat. In order to ensure a gas-tight joint, the piston is fitted with what are known as compression rings which exert a pressure on the cylinder walls. See PISTON RING.

PISTON PIN, see GUDGEON PIN.

PISTON RING. A split ring, generally made of cast-iron, which fits in the grooves provided in the



Cut-away view of piston and gudgeon pin as fitted in De Havilland "Gipsy" aeroplane engines.

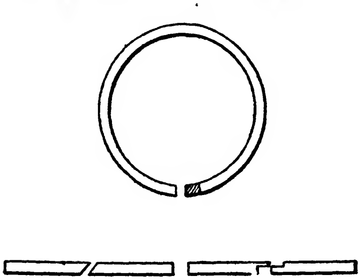


PITCH IN ELECTRICAL MACHINES

Diagram of a four-pole machine (a) shows how pole pitch is measured; coil pitch is illustrated at (b) while teeth and slots (c) show meaning of slot pitch.

piston of an internal-combustion engine. It is so proportioned that, when in position, it springs outwards against the wall of the cylinder and ensures a gas-tight fit. The ends of the ring are shaped to overlap; this is done by cutting them diagonally or stepping them as shown in the accompanying diagram.

It is very important when fitting new piston rings not to fit them so tightly that the two ends abut, or, as the engine heats up, the ring will either break, or the piston seize in the cylinder. To fit a new ring, insert it in the cylinder and measure the gap between the two ends with a feeler gauge. This should measure approximately 0·001 per inch of cylinder bore; i.e., when cylinder bore is 3·5 in. the gap should be 0·0035 in. It is much better to have too large than too small a gap.



Rings fitted to pistons of internal-combustion engines ensure a gas-tight fit between piston and cylinder wall.

PISTON SEIZURE. When a piston sticks in the cylinder of an internal-combustion engine it is said to be seized. This condition results from lack of lubrication or incorrect fitting of piston or piston rings.

PISTON SLAP. The noise produced in an internal-combustion engine by loose-fitting pistons; it is particularly noticeable when an engine is cold, as immediately after starting up. It is largely overcome by employing a split skirt, which yields slightly under pressure, and enables a better piston-fit to be obtained under all conditions.

PITCH (Carpentry), see TIMBER.

PITCH (Elec. Engineering). A measurement of distance used in connexion with electrical machinery. Pole-pitch is the circumferential distance between the centre lines of adjacent poles and is measured in inches or centimetres. Coil-pitch is, similarly, the distance between the centre lines of the sides of a coil, but it is often expressed in terms of slot-pitches or angle subtended at the centre as shown in the diagram. Synonym: coil-span. A full-pitch coil is one whose pitch is equal to the pole pitch. Slot-pitch is the distance between the centre lines of adjacent slots.

PITCHED ROOF. A lean-to roof is a single-pitched roof, but the term is commonly applied to roofs of double or multiple slope whose

surfaces have a distinct inclination to the horizontal. Care must be taken to ensure that the angle of pitch is sufficient for the type of roof covering so that water cannot seep up between the lapped joints.

The minimum pitch required for general purposes can be taken as: slates 30 deg., tiles 40 deg. The surfaces of so-called "flat roofs" have enough pitch or slope only to enable the water to flow to gutters, the roof surface being divided into gently sloping planes. See ROOFS.

PITCHING AXIS, see AXIS.

PITCHING MOMENT, see AEROFOIL SECTION.

PITCH PINE. There are several pines, to be found in the south of the U.S.A., marketed under this name, but longleaf pine is the best. It is used for heavy structural work and carpentry, and joinery that is to be varnished. There is considerable difference between the yellow springwood and the dense, reddish summer wood, which gives a bold handsome grain. It is difficult to paint because of the resin.

PIT MOULDING. A form of moulding in which the lower part of the mould is made in a pit in the foundry floor, intermediate parts and the cope being made in boxes in the usual way. A description of the method is given under the heading BEDDING-IN.

PITOT HEAD, see AIR-SPEED INDICATOR.

PIVOTED SASHES, see WINDOWS.

PLANE. A cutting tool with an adjustable iron or knife, by means of which the depth of the cut is regulated. It is used in woodwork for smoothing surfaces. Planes, of which various types are illustrated on the opposite page, are made of wood or metal.

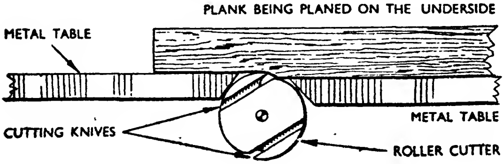
Bench planes (smoothing, jack and trying planes) are usually of the wooden variety, with the addition of a metal smoothing plane. Wood planes are of beech, and in the best qualities the grain is straight, close and compact with the medullary rays at right-angles to the sole. They should be soaked in raw linseed oil before use, and the surface should occasionally be wiped with oil. The iron should be knocked back when the plane is not in use. With the smoothing plane this is done by tapping the back-end, or heel, with a mallet or hammer, while jack and try planes are tapped on the top of the front end, or nose.

The *rebate* plane is of wood, but its metal counterpart, called a *shoulder* plane, is used for difficult hardwoods and end grain. The metal *compass* plane for circular work has superseded the wood type. Most joiners have a metal *block* plane and *bullnose* plane, of which there are numerous varieties.

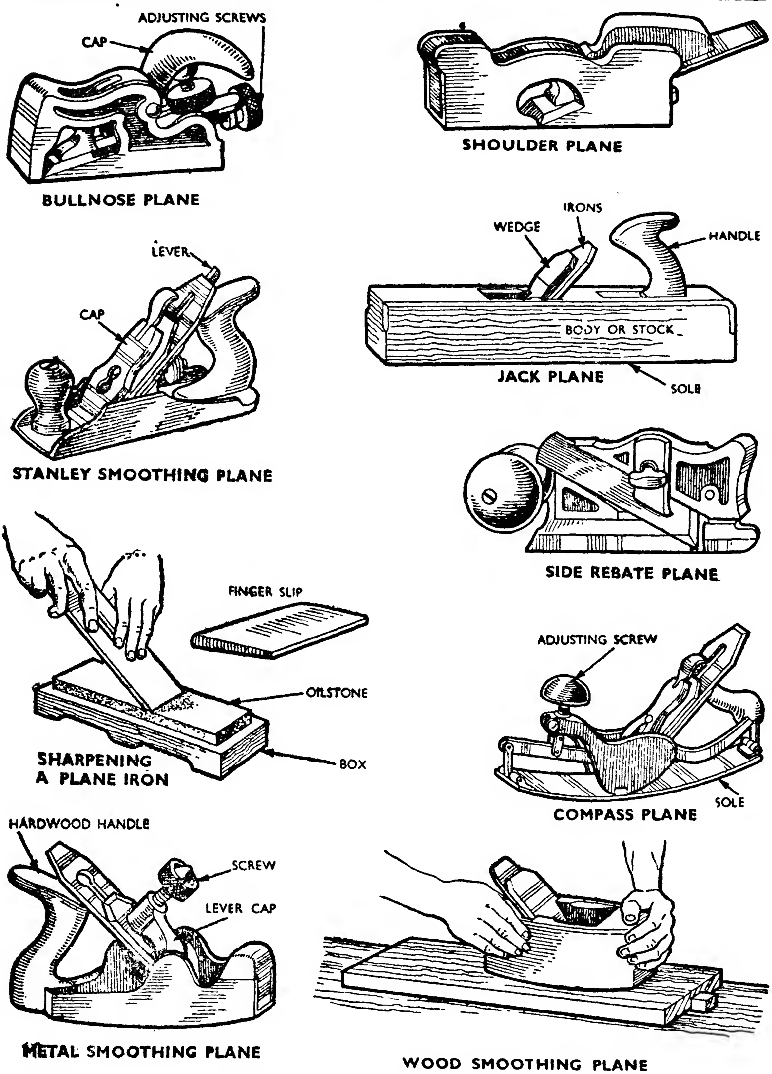
A *side-rebate* plane is necessary for cleaning up grooves. There are many registered designs of all types of plane, both metal, and combined wood and metal. *Moulding* planes have been superseded by machines and by the Stanley Universal plane.

For *sharpening* the iron, a good, keen oilstone (q.v.) is essential. A few drops of a mineral oil are first poured on to the stone; the plane iron is then rubbed steadily to and fro at the correct angle. The method of holding a plane iron is shown in the illustration. The tool should be held pointing away from the operator, and pressure exerted on the forward stroke. When a sufficiently sharp cutting edge has been obtained, the tool should be turned over, laid flat on the stone, and rubbed lightly once or twice to remove the wire edge.

PLANING MACHINE (Joinery). A belt- or motor-driven machine, designed for planing, surfacing, jointing and chamfering. By means of a



Section of a planing machine showing rotating roller-cutter working between edges of two metal tables set at different levels—exaggerated in the diagram.



PLANES USED IN WOODWORK

Various types of plane, both wooden and metal, are used in carpentry for smoothing surfaces. Shape and size vary enormously, in each case being adapted to the particular purpose for which it is intended that the implement shall be used.

rapidly revolving cutter-block, working between the edges of two metal tables set at different levels, as shown in the illustration, the operator is able to plane a board or plank simply by pushing it along the lower table.

PLANING MACHINE (Mech. Engineering). A machine tool in common use for machining flat surfaces on castings or forgings; it is also possible to use it to machine curved surfaces. There are several

varieties of planer, differing principally in the disposition of the columns and slides carrying the tools, as well as in the arrangements for the traverse or feed.

Normally a planer embodies a reciprocating horizontal table to which the work is rigidly attached, the cutting tool or tools remaining stationary. But certain types intended for very heavy or awkward castings are arranged so that the work is bolted to a fixed table, the tools being clamped in slides which are moved to and fro over the surfaces to be machined. Open-side planers have a single massive column on one side of the table, with a cross-rail or beam carrying the cutting tools; the open side enables the range of work which can be tackled by such machines to be much increased.

In the ordinary planer, however, one or two cutting tools are attached to a horizontal slide bridging the gap between two columns, one on each side of the table. The table receives its motion from a reversible rack-and-pinion gearing. *Crank* planers are provided with some form of crank, usually in the style of the Whitworth quick-return motion, for moving the table; they are made chiefly in the smaller sizes and are useful for the rapid production of components involving short-stroke work. *Duplex* planers have housings, each provided with a cross-rail and tool heads, at either end of the bed, the housings being adjustable so as to vary the distance between the cutting tools.

MATERIAL	CUTTING SPEED (ft. per min.)
Cast-iron, roughing	40–50
Cast-iron, finishing	20–25
Wrought-iron, roughing	30–45
Wrought-iron, finishing	20
Steel castings, roughing	30–35
Steel castings, finishing	20
Machinery steel	30–35
Bronze and brass	50–60

The tools face opposite directions, so that, every stroke being a cutting stroke, either for one housing or the other, the idling stroke is avoided. Planer cutting speeds are reckoned on the net cutting travel of the tool and not on the total distance through which the table moves, as that would include the idling period. The accompanying table gives the approximate range of cutting speeds for planer tools.

PLASKON, see GLUE.

PLASTERBOARDS, see WALLBOARD.

PLASTER OF PARIS. A finishing material obtained from hydrated sulphate of lime, known as *gypsum*. The water of crystallization is expelled by placing the gypsum, in the form of small lumps, in a pan, roasting it over an open fire, and grinding the residue to a very fine powder.

There are three grades of plaster of Paris—superfine, fine and coarse, and the varieties are known as *pink* or *white*, *coarse* or *fine*, *quick* or *slow-setting*. Plaster of Paris sets quickly when mixed with water, and is used for the finishing coats of internal wall surfaces, cornices, enrichments etc.

When used alone, plaster of Paris may be painted with oil paint as soon as bone dry, but if incorporated with slaked lime it must be allowed to stand for at least twelve months before a satisfactory finish can be guaranteed. See CALCIUM.

PLASTERWORK. The covering or finish usually applied to walls and ceilings, now often replaced by wallboards or pressed-fibrous material, or combined fibre and plaster. When the walls are of brick, a key is made by raking out the joints, after which the coarse stuff (q.v.) can be applied.

On timber-framed walls and ceilings, however, the necessary grip for the plaster material is provided by a bracketing, or cradling, of wood or metal. Either wooden laths are nailed across the studs or joists, with spaces a little over a quarter-of-an-inch between, or expanded metal

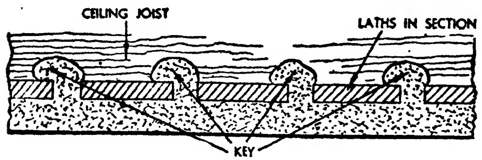


Diagram showing method of using wooden laths to provide adequate support for ceiling plaster.

framework, often known as cradling, is fixed to hold the coarse stuff. This latter, mixed with hair, squeezes through the spaces between the laths and curls over as shown in the illustration, so that, on setting, the whole surface becomes firmly attached to the support or backing.

When this rough surface is dry, a coat of finer plaster is floated, which, in turn, may be distempered or papered.

A plasterer's tools, all of which are described under their separate headings, consist of float brushes, gauging and laying trowels, gig-stick, hawk, joint-rule, lath-hammer and straight-edge. See LATH AND PLASTER.

PLASTIC FLOW (Metallurgy). Permanent deformation produced in a metal or alloy by the action of stresses. At loads below the yield point, plastic flow is believed to occur mainly at the grain boundaries of the material, resulting in a very slow but continuous change in the dimensions of the part.

The rate of flow, or creep as it is more generally termed, increases with rise in temperature and load. In designing machine parts to run at elevated temperatures, it is therefore necessary either to use materials resistant to creep, or to reduce the working loads so that the amount of creep occurring during the working life of the part is negligible.

At stresses above the yield point plastic flow is not confined to the grain boundaries, but takes place within the grains, resulting in a much larger degree of deformation. Under these conditions, each grain deforms under the action of shearing forces, distortion occurring by a process of slip along the crystal planes of the grains. In a material under tensile load, the maximum shear stress is at 45 deg. to the axis of the applied stress, so that distortion occurs first in those crystals oriented in this direction (see ORIENTATION). As the load is increased, the process of slipping spreads to other crystal grains until all are distorted. The amount of deformation that can be produced is limited, any attempt to go beyond the limit resulting in fracture of the material.

PLASTICS. A word now used with a popular rather than a scientific meaning. The modern use of the word covers such substances as shellac, celluloid, Bakelite, artificial rubber, nylon, Perspex and many other substances. They differ greatly in chemical composition and in behaviour, and there is no very logical system of classification for them. They are very widely used and will be even more widely used in the future. They have this common property, that they can be moulded, cast, or extruded, and will retain their shape.

Some plastics are "thermoplastic", that is, they soften on heating and become hard again on cooling, and will again soften on heating. Other plastics are "thermosetting", that is, they are softened by heat and can then be moulded, but the process cannot be repeated; once the moulded body has set and cooled it cannot again be softened. Some plastics, e.g., shellac and the casein plastics, are to some extent intermediate between the thermoplastic and thermosetting types.

The oldest plastics are those which occur in nature, such as shellac, bitumen, gilsonite and rosin. The newer ones are classified in accordance with their properties and their chemical constitutions. The principal thermosetting compositions are the phenol-formaldehyde resins, the urea-formaldehyde resins and the alkyd

resins. The thermoplastic compositions are: the cellulose esters and others, the ethenoid polymer plastics, the coumarone and indene resins, the chlorinated rubber products, the synthetic paint resins and the casein plastics.

PLATE. The electrode of a secondary battery; also an obsolescent term for the anode of a radio valve. See ANODE and RADIO VALVE.

PLATE GLAZE. A smooth effect, also known as P.G., given to paper by passing a small pile of alternate paper sheets and highly polished copper or zinc plates between polished steel rollers under firm pressure. It is applied to hand-made papers to assist writing, also to certain lithographic transfer papers, e.g. rolled Scotch.

The paper is also consolidated by this process and made thinner and stronger to the point of retaining the fibre formation. Excessive pressure bruises the fibres and weakens the paper. The advantage is that the process does not affect the colour of the paper, but because of slowness of production, and consequent high cost, it is not often used.

PLATEN MACHINE, see PRINTING MACHINES.

PLATE PATTERNS AND PLATE MOULDING (Foundry). In plate patterns the various parts are fixed on one or both sides of a plate which takes the place of a turn-over board. The plate is larger than the box with which it is used, and is provided with two holes which fit the dowels on the box.

By fitting a half-box to each side of the plate and ramming both sides, a complete mould is obtained. The plate ensures a straight draw, and a minimum of damage is caused in the mould. It also ensures the production of joint faces which fit accurately. Whenever possible, runners and risers and gates should form part of the pattern, and as many as possible should be mounted on one plate.

In this way some of the most skilled of moulding operations—the cutting of runners and risers, the making of a joint between half moulds, and mending-up—are avoided, with the result that semi-skilled labour may be employed. The pattern plate need not be flat, but may be shaped to give a convenient joint in the mould.

Patterns of a deep cylindrical shape require the use of a stripping plate, through which the pattern projects. The pattern may be withdrawn, leaving the stripping plate in position covering the entire joint face of the mould and thus preventing damage. The pattern must, of course, be made

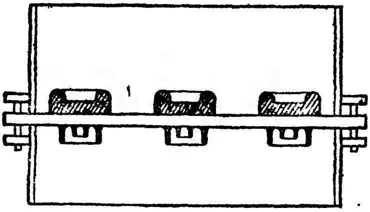


Plate pattern assembled in moulding box.

longer to allow for the thickness of the stripping plate.

Plate patterns used for machine moulding are similar but the plate is smaller, fitting into a register on the moulding press table. Dowels on the table are used to locate the moulding boxes.

PLATINUM (Pt). Atomic no. 78; atomic wt. 195·23. A silvery metal, very malleable and ductile, durable, hard and not easily corroded; it is resistant to most acids, but is attacked by aqua regia. Platinum, especially in a finely divided state such as platinum black or spongy platinum, is a valuable catalytic agent.

Platinum catalysts are used on a considerable scale in the manufacture of sulphuric acid and in the oxidation of ammonia to nitric acid. Platinum and its alloys are used in dentistry, in jewellery and in many scientific instruments and processes. It is di-, tri- or tetravalent, forming chlorides, $PtCl_2$, $PtCl_3$ and $PtCl_4$, and bromides, $PtBr_2$, $PtBr_3$ and $PtBr_4$.

In its chemical properties it resembles ruthenium, rhodium, palladium, osmium and iridium. It is found alloyed with gold, iridium and

other metals, principally in Russia and Colombia and in smaller quantities in Canada and the United States.

PLUMBAGO. Natural graphite; grey to black in colour, and of a greasy nature resembling French chalk in texture. It is an excellent refractory and is used for making the best crucibles. It is also used as a mould dressing, either dry for green-sand moulds, or wet, with admixed clay, for dry-sand work. See GRAPHITE.

PLUMBING. Any work connected with water supply or drainage, including metal roof and gutter coverings. The word is derived from the Latin *plumbum*, meaning lead, and was originally applied because the pipes and material used in plumbing were mainly of that metal.

In modern plumbing, however, many other materials are used, including copper, cast-iron, wrought-iron etc. Copper tubing has the advantage of a smooth bore and is easy to fit; the joints can be rapidly made, whether by compression, welding or soldering, and the economy of labour costs thus achieved frequently outweighs the extra cost of copper as a material. Wrought-iron piping, properly protected from rust and corrosion with a coating of zinc (galvanized), is also much in favour, but should not be used in districts where soft water, or water of an acid nature, is liable to attack these metals. Both wrought iron and copper can be easily fixed, with elbow joints at changes of direction, but wrought iron, although cheaper in the first place, is always liable to rust and offers more resistance to the flow of water owing to its rougher internal bore.

Lead pipe has numerous advantages. It has a smooth bore, is non-corrosive and non-rusting. Further, it is easily bent, and does not require shaped unions. Owing to its softness, however, it has to be well supported, and the method of joining the various sections with a wiped-soldered joint calls for considerable skill and craftsmanship. Lead pipes may be obtained alloyed with small percentages of cadmium, tin and tellurium; they are tougher and stronger than those of pure lead.

Pipes for the discharge of sewage or waste water are usually of from 2 to 4 in. in diameter, and are made of cast-iron, lead, glazed stone and earthenware, or asbestos (see PIPE JOINTING AND FIXING). Drains should be laid so that they are self-cleansing, with proper falls (q.v.), and to conform with local councils' requirements (see DRAINAGE).

Roofwork (q.v.) consists mainly of laying sheet lead, copper or zinc, so that roofs are rendered water-tight. Lead or zinc are the most common materials used for this purpose and, apart from flats (roofs which are almost flat, covered entirely with lead as the main material) the metals are used chiefly to cover connexions that would otherwise not be water-tight—over the ridge, round chimney stacks, in box and valley gutterings, over copings etc.

PLUMB-LINE. A line having at one end a weight, usually pear-shaped, widely used in building construction for obtaining a true vertical. The line is suspended from the point at which a vertical reading is required and the plumb-bob, or weight, allowed to swing gently until it comes to rest. The line will then indicate, by the position it assumes, a true perpendicular.

PLYWOOD. Thin veneers, or layers of wood, glued together under pressure, with the grain running in opposite directions. Plywood is continually becoming of greater importance in joinery owing to improvements in manufacture, especially in the glues used for securing the veneers together.

Good plywood is much stronger than ordinary wood, and is much more stable. The best qualities are now resin bonded, resistant to peeling and bubbling, and are water- and fire-resisting.

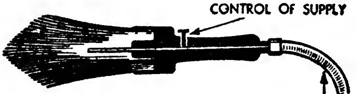
Casein glues are also extremely good and extensively used. Plywood varies from $\frac{1}{32}$ in. to over 1 in. in thickness, and from 3-ply to 36 alternating

laminations or sheets. It may be made to almost any size to suit special requirements, but standard sizes are up to 10 ft. long and up to 5 ft. wide; special sizes go up to 16 ft. and 8 ft. The first dimension denotes the direction of the grain on the face. The thickness is stated in millimetres, and 3-ply is usually from 3 to 6 mm. and 5-ply from 6 to 12 mm.

For thicknesses over 9 mm., almost any number of plies may be used. Superior plywoods may be faced with sawn or sliced veneers, but ordinary plywood is built up of rotary-cut veneers. American plywood is made of Douglas fir, maple, gum, alder, birch, ash, oak, or red pine. European is similar, excluding Douglas fir and gum, but with the addition of Gaboon mahogany. Australian is chiefly hoop pine, silky oak, walnut and maple.

The qualities are graded according to the defects in the faces, from AA to BB, but Gaboon plywood is graded as Crown, and 1-, 2- and 3-star. Ordinary plywood veneered with decorative wood after manufacture is called *veneered* stock. If the decorative veneers are included during manufacture it is *built-up* stock. Metal-faced plywood may be faced with stainless steel, copper, galvanised iron or aluminium. Plastic compounds, bakelite etc., are also used as facings. See LAMINATED BOARD.

PNEUMATIC PAINT BRUSH. This contrivance resembles an ordinary painting brush but, as shown in the accompanying illustration, provision is made for the paint to be delivered within the bunch of bristles as a fine jet under pressure. Its use accelerates the process of applying paint so that it may satisfactorily compete with spraying. Further, it meets the requirement that the priming coats of red lead shall be applied to the surface of ironwork by brushing.



Pneumatic paint brush showing method of controlling supply to bristles.

POINTING. A process of finishing the mortar joints between stones and between bricks, by which character is given to the work. There are various forms of joint finishings to brickwork, the following being the ones generally adopted:

(1) *flush* or *flat joints*, in which the mortar is struck-off flush with the face of the bricks;

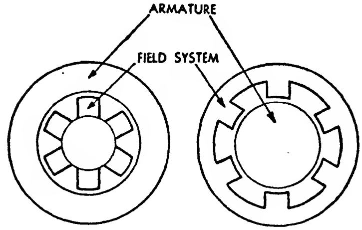
(2) *struck joints*, in which the mortar is pressed into the joint by means of a trowel (q.v.), thus giving a bevelled appearance;

(3) *tuck pointing*, in which a shallow channel is formed to the true outline of the brick-bond and the grooves are filled with lime putty, which is allowed to project slightly from the face of the brick-work.

POLARIZATION. A phenomenon in a primary or electrolytic cell which causes a back-e.m.f. to be produced by the products of the electrolytic action. In a Leclanché cell the carbon electrode is surrounded by a de-polarizer to remove the hydrogen bubbles which would otherwise cause polarization and loss of e.m.f. (see DEPOLARIZATION). The term is also used to mean the magnetization of, for instance, a piece of iron placed in a magnetic field. A polarized relay is one which contains a permanent magnet so that it is sensitive to the direction in which current flows.

POLE. (1) In an electrical machine, one of the places in the magnetic circuit at which the flux crosses the air gap; thus a six-pole machine is one in which the lines of force enter the rotor or stator at three places and emerge at three other places. Both the rotating-field and rotating-armature type of machine are shown in the diagram (see MOTOR and SALIENT POLE).

(2) One of the points of a magnet at which the lines of force are most concentrated (see also UNIT POLE): these points are normally close to the



Six poles may easily be distinguished in each of these two diagrams, but in many machines the number of poles can be found only by tracing out the winding, or testing, because there are no actual projections as in this case.

ends, the exception being consequent pole (q.v.).

(3) The term is also applied to the terminals of an electrolytic cell (q.v.), or a source of e.m.f.

POLE-CHANGING. A method of altering the arrangement of the windings of an electrical machine, generally an induction motor, in order to change the synchronous speed (q.v.) of the machine.

POLONIUM (Po). Atomic no. 84; atomic wt. 210. A radioactive element discovered in pitchblende; its radioactivity consists of the emission of α rays and γ rays and the formation of radium G, an isotope of lead. Polonium belongs to the sulphur group, and a few compounds have been prepared that show the element to be divalent, trivalent and tetravalent.

POLYMERIZATION, see POLYMERS.

POLYMERS. Aggregates, usually chains, of similar chemical groups. Thus starch is a polymer of glucose. Polymers of isoprene resemble india-rubber. Most of the plastics (q.v.) are polymers, in which the long chains are connected to each other by side linkages. The process of forming polymers is known as *polymerization*.

POLYPHASE. An electrical system, machine, or device which generates, transmits, or receives two or more voltages whose vectors normally have some fixed phase relation to one another. See ALTERNATING CURRENT, TWO-PHASE SYSTEM and THREE-PHASE SYSTEM.

POROSITY. The term applied in tinplate manufacture to the microscopic discontinuities which exist in all but the heaviest tin coatings. A *pore* may be defined as a small local exposure of the steel base. *Normal* pores are discontinuities in both the free tin and the compound layer of the coating, and their occurrence is generally considered to be due to the presence of non-reactive sites on the steel surface. *Potential* pores are sites where the discontinuity is only in the free-tin part of the coating, the tin-iron compound layer being intact. Owing to the brittleness of the compound layer, potential pores are particularly liable to breakdown, and form actual pores when the tinplate is subjected to bending and forming operations.

Although no exact distinction can be drawn, the term pore is usually reserved for discontinuities which are so small as not to be discerned by the naked eye. The term *uncoated spot* is used to indicate an exposure of the steel base which is sufficiently large to be noticed by the assorter.

PORTLAND CEMENT. An artificial cement produced by mixing, and calcining, i.e. subjecting to considerable heat, certain materials which will yield silicates and aluminates of lime. It is obtained from the natural mechanical combination of lime with silica and alumina.

The ingredients are first ground and mixed in grinding mills and then made into the form of slurry, or thin paste, in a wash mill and conveyed to storage tanks. The slurry is then passed through rotary kilns, coal dust being blown in at the lower end and ignited; it is here subjected to a temperature of about 1700 deg. C. The slurry is thus converted into a clinker, and whilst in this form is conveyed to grinding mills, where it is ground to a very fine powder ready for use.

POSITION ERROR. In aeronautical engineering, the position error, or,

more correctly, pitot-head position error, is an error which is introduced into the reading of the airspeed indicator when the pitot head is placed in such a position on the aeroplane that the static tube is in a region where the static pressure is not the same as it is in free air.

POTASSIUM (K). Atomic no. 19; atomic wt. 39·104. A very common element contained in many minerals, in sea water and in the ashes of plants. It is a soft silvery metal, density 0·859, m.p. 62·5 deg. C., b.p. 762 deg. C. If a small lump of potassium is thrown on to water it attacks the water, forming potassium hydroxide and hydrogen; the heat generated is sufficient to light the hydrogen.

Potassium oxidizes very rapidly, and must be kept away from water or air. It is a monovalent element, forming a very large number of compounds, e.g. potassium bromide, KBr, a valuable drug, potassium chlorate, $KClO_3$, potassium cyanide, KCl, a powerful poison, potassium hydroxide KOH (caustic potash), potassium permanganate, $KMnO_4$, and potassium sulphate, K_2SO_4.

POTENTIAL. The electrical potential difference (q.v.) between a point and earth.

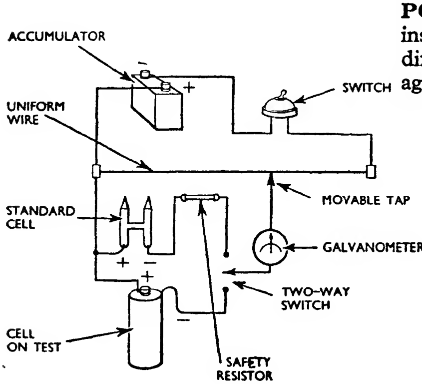
POTENTIAL DIFFERENCE. Symbol: V. Abbreviation: P.D. The amount of work which has to be done by, or is expended upon, a unit quantity of electricity when it is moved from one point to another. The practical unit is the volt (q.v.). For practical purposes, potential difference is the reading of a voltmeter, which takes no current, connected between the two points.

POTENTIAL GRADIENT. The rate of change of electric potential at a point measured in the direction of the electric force at that point. It is often expressed in kV/cm. and is of importance in the design of insulators, cables, bushings etc. If the potential gradient at a point is greater than the dielectric strength (q.v.), then the insulation breaks down, even though the total voltage divided by the total distance may appear to indicate an adequate factor of safety. In a concentric cable, for example, the potential gradient is much greater at the surface of the conductor than at the inside of the lead sheath. See CORONA.

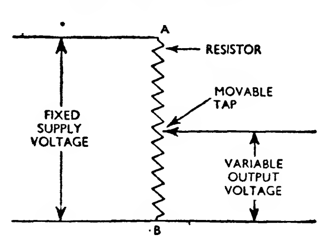
POTENTIAL PORES, see POROSITY.

POTENTIAL TRANSFORMER, see VOLTAGE TRANSFORMER.

POTENTIOMETER. An electrical instrument wherein the potential difference to be measured is balanced against a measurable fraction of a



(a)



(b)

Simple potentiometer (a) for measuring the e.m.f. of a cell. The position of the tap is adjusted to give no reading when (1) a standard cell is in circuit, and (2) the test cell is in circuit. The relative distances of the tap from left end of wire indicate the e.m.f. ratio of the cells. In (b), when the movable tap of potential divider is at A, the output voltage is the same as that of the supply. As the tap is moved towards B the output voltage falls until at B it is zero.

known potential difference. The illustration shows at (a) a simple form of potentiometer. A potentiometer rheostat or potential divider is a means of obtaining a variable voltage from a fixed supply voltage, as shown in the diagram at (b).

POUNCING, see GILDING.

POURING BASIN, see RUNNER BUSH.

POURING TEMPERATURES. The following table gives suitable casting temperatures for various non-ferrous alloys when pouring into sand moulds.

ALLOY	CASTING TEMPERATURE DEG. C.
Aluminium Alloys	700 to 760
Aluminium Bronze	1175 „ 1200
Brass	1130 „ 1150
Gun Metal ..	1150 „ 1200
Lead Bronze ..	1100
Manganese Bronze	950 to 1000
Phosphor Bronze	1025 „ 1150

The figures given form a useful guide, but should be modified according to the class of work made. In general, casting temperatures should be on the high side for light work to avoid danger of short runs. Lower temperatures will be beneficial for heavy work in that less dross is likely to be formed. Whenever possible, temperatures should be measured by means of an immersion pyrometer. Judging temperatures by the eye is difficult and unreliable.

POWDER METALLURGY. The art of making metallic articles from metal powders. In recent years the process has been very largely used for making hard-metal carbide tools and parts of motor cars and aeroplanes. Porous bronzes are made by mixing powdered copper and tin, pressing the mixture in a hydraulic or other kind of press, and heating the pressed article to a temperature of about 750 deg. C. Such bronzes are used for bearings. Hard-metal carbide tools are made in the following way. Pure tungsten oxide is reduced by hydrogen to make a tungsten powder which is mixed with powdered carbon and heated to produce tungsten carbide powder. In a similar way cobalt powder is made, and this is mixed with the tungsten carbide powder; the mixture is ball-milled, pressed into the required shape by hydraulic pressure, and then heated to about 1400 deg. C. Electric contact metals and magnets are made by similar methods.

POWER. Symbol: P. The rate at which work is done. The electrical unit of power is the watt (q.v.). In a D.C. circuit the power in watts is given by: P equals V (volts) multiplied by I (amps.), whereas in an A.C. circuit the relation is: P (watts) equals V.I.cos ϕ, cos ϕ being the power factor (q.v.).

POWER AMPLIFIER. A radio-valve amplifier so designed and operated as to give power output at its anode circuit. See VALVE AMPLIFIER.

POWER COEFFICIENT, see PROPELLER COEFFICIENTS.

POWER FACTOR. The ratio of the power in watts in an A.C. electrical circuit to the product of voltage and current. Thus:

$$\text{power factor} = \frac{\text{Watts}}{\text{volts} \times \text{amps}}.$$

For sine waves only, it is equal to cos ϕ, where ϕ is the phase-angle difference between current and voltage. See ALTERNATING CURRENT.

POWER-GRID DETECTION. In radio, leaky grid detection with low values of grid condenser and leak, usually about 0·0001 microfarad, and 0·5 megohm respectively. Sensitivity is lost, but higher transmission modulation can be accepted with less frequency distortion.

POWER PACK. A term applied to electrical apparatus used for converting, transforming or smoothing the supply from public supply mains to make it suitable for operating radio apparatus. For use with A.C. mains, it usually comprises a transformer, rectifier and smoothing circuit

for H.T. supplies, and provision for L.T. current for valve heaters. Arrangements for grid-bias supplies are often included.

POWER PRESS AND PUNCHING MACHINE. These are machines which, usually, by virtue of energy stored in flywheels, can shear out pieces of material (metal) to a required shape, or press a previously cut-out shape to the requisite form over a "blank". They form the principal item of equipment for the production from sheet metal of a wide variety of articles which may range from the thinnest sheet to boiler plate. Thus the extent of this range implies a similar variety of sizes and outputs in the machines themselves.

Punching machines are properly those restricted to the cutting of circular holes in sheet metal, whilst power presses generally may be used for *blanking* (cutting the required shape from the metal), *piercing* (the cutting of any shape of hole in the blank), *swaging* or *upsetting* (altering the thickness by pressure), *drawing* (pressing a punch into a blank so as to form it into a cup-shaped vessel) and *bending* or *forming* (production of bends with either sharp or radiused corners).

The largest machines may be up to 20 ft. high, with ability to exert a maximum pressure of over 1,000 tons. The *single-action* press is supplied with a single ram, and thus a single punch; the *double-action* press embodies two independent rams working one inside the other. The motive power of the presses is usually derived from an electric motor driving a heavy flywheel which acts as a reservoir to meet the large draining of energy during the power stroke. The rotary movement of the motor, geared down to a suitable operating speed, is transmitted to the ram either by a crank motion which gives a sudden heavy pressure—almost an impact—or by a toggle action, allowing more gradual squeezing of the metal.

Presses are usually operated by a pedal which brings a clutch in the flywheel either into or out of engagement. A brake is usually fitted, being sometimes linked to the pedal so that it acts only when the operator releases the pedal. The brake should be so adjusted that it will just prevent the weight of the ram of the machine from causing the crankshaft to revolve.

PRECIPITATION HARDENING, see AGE-HARDENING.

PRE-SELECTION CIRCUITS. Tuned circuits between the aerial and the frequency changer of a superheterodyne radio receiver. See SUPERHETERODYNE RECEIVER.

PRESS BRAKE. A machine for folding, or imparting similar deformation to, sheet metal. In appearance the press brake closely resembles the guillotine, having two sturdy housings with upper and lower "knife-pattern" tools. It is not, however, necessary to have one pair of tools only in the machine, as it is possible to accomplish more operations in the following way.

The desired number of tools (e.g. four) for follow-on operations are fastened along the jaws; it is then possible to pass the component one place to the right after each stroke, control being exercised by the operator at the extreme right. Press brakes are most often used for forming channel sections, cap strips and the like.

PRESSED-FIBRE BOARD. A sheet of synthetic wood, made from fibrous material or vegetable products finely shredded and synthesized into a homogeneous sheet without grain.

The chief characteristics of fibre boards are:—

(1) they are less liable to movement under changes of temperature than ordinary timber;
(2) their insulating and sound-absorbing properties.

Fibre boards are used for many purposes in building construction, such as covering the framework of wood stud partitions, ceilings, and for insulating in the construction of pitched and flat roofs.

PRESSING. In metallurgy, a process

wherein metal, either hot or cold, is shaped between dies in a press. Billets, bars, slugs or blanks are squeezed to shape as under a drop-stamp or steam-hammer, but with the essential difference that deformation is accomplished at a rate which, although sometimes fairly rapid, does not assume the nature of a sudden blow.

Sheet-metal is also shaped by pressing, and no accepted definition at present exists to distinguish between *pressing* and *deep-drawing*. Usually the formed shape is called a pressing when it is shallow, but sometimes quite deep shapes are still referred to as pressings.

One suggested distinction, however, is that pressing should be used of processes in which the walls of the article are not thinned deliberately by "ironing" (although they may be thinned by natural stretching), whereas deep-drawing should be reserved to describe processes in which the walls of the article are thinned, by design, during their passage through the die itself. The term deep-pressing might be used to describe the formation of deep articles by the first process.

NOTE: "Ironing" implies that the clearance space between the punch and the die is less than the thickness of the metal entering the die.

PRESSURE CABIN. A cabin of an aeroplane in which it is possible to maintain, when flying at great altitudes, the internal pressure at a value equal to that of the atmosphere at low altitudes.

This is achieved by sealing all joints, holes etc. and fitting a supercharger with control valves and other necessary gear.

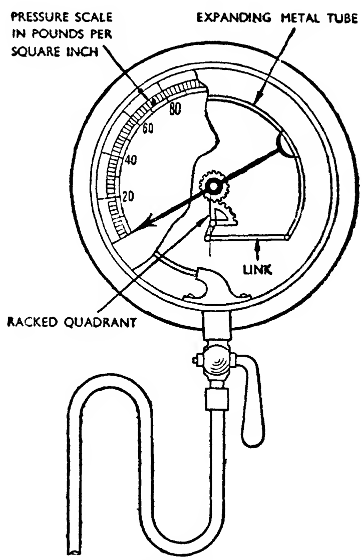
It is necessary to keep up the pressure when flying at great altitudes as the oxygen, because of the reduced pressure, is not capable of being absorbed into the blood. While it is possible to breathe pure oxygen from a supply carried in the aeroplane, and so to increase the altitude at which it is possible to live, modern aircraft are capable of operating above the altitude at which an oxygen supply alone is sufficient.

A pressure cabin is thus required under two conditions. First, on civil aircraft operating at heights of approximately 10,000 ft., where passengers cannot be expected to breathe pure oxygen from a mask. Secondly, on military aircraft which are capable of flying at altitudes at which man cannot live even when inhaling oxygen.

PRESSURE DIE CASTING, see DIE CASTING.

PRESSURE ELECTRIC, see PIEZO-ELECTRIC.

PRESSURE GAUGE. A device for indicating the internal pressure in boilers, compressed-air reservoirs etc. The mechanism of a Bourdon pressure gauge, a type in general use, is shown



Mechanism of a Bourdon pressure gauge.

in the illustration. Steam is admitted to a thin, spiral spring of flat or oval section, which tends to straighten under pressure. The reason for this is that a cylinder of circular cross-section has a greater volume than one whose cross-section is an oval of equal circumference; the steam, there-

fore, expands the oval to a circle, and the tube, closed at the other end, tries to form a straight line.

The closed end is connected through a link to a quadrant rack, geared to a small pinion fixed to the back of a pointer, and this moves over a scale, only a part of which is shown, graduated in lb. per sq. in. As the pressure of the steam increases, the free end of the tube moves outwards. This causes the quadrant to move on its pin, revolving the pinion wheel and moving the pointer round the dial. When the pressure falls the motion is reversed by the inherent springiness of the tube, which returns to its former shape.

PRESSURE RATIO, see COMPRESSION RATIO.

PREVENTIVE COIL. A reactor connected between the halves of a tap selector of, for example, an electrical transformer, to limit the current which flows when adjacent tappings are bridged. The line is connected to the mid point of the reactor. A number of additional tap positions may be obtained, if the reactor is continuously rated, by having the two selectors on adjacent taps instead of both being on the same one.

PRIMARY CELL. An electrolytic cell in which electricity is produced by chemical action. It differs from a secondary cell in that it cannot be recharged electrically. To recharge a primary cell one or more of the active materials must be renewed. See DRY CELL, DANIELL CELL and LECLANCHÉ CELL.

PRIMARY CIRCUIT. The low-tension circuit in an ignition system. See INDUCTION COIL.

PRIMARY WINDING. The winding of an electrical machine, particularly a transformer, connected to the source of supply. See SECONDARY WINDING.

PRIME MOVER, see INTERNAL-COMBUSTION ENGINE, STEAM ENGINE and TURBINE.

PRIMING (Painting). The first coat of paint applied to any surface to fill the pores and form a hard surface. Priming must always be freshly made from pigments ground in refined linseed oil, paste driers and genuine turpentine or white spirit.

The balance between the linseed oil and the diluent depends upon the absorbent character of the ground; for open-grained timbers and dry-lime plaster the proportions are: oil three parts, diluent two parts; for close-grained timbers, dry hard wall plasters, iron and other firm surfaces the proportions are: oil two parts, diluent three parts. The best pigments for priming plaster and timber are genuine white lead tinted with not more than 5 per cent of red lead; for ironwork, red lead only.

Many proprietary primers are pre-fabricated and marketed ready for use. The use of old fat paint (smudge), the aggregate of leavings from other jobs, as priming is unsatisfactory. The partially oxidised oil content prevents penetration of the surface and creates a film which is too elastic to withstand the surface strain developed by the ageing of the super-imposed paint.

PRINCIPAL FOCUS, see FOCUS.

PRINTER'S DEVICE. A design, usually heraldic in treatment, used by early printers as a trade mark. It served as a distinguishing feature of the work of the owner as well as a mark of good faith to customers; probably an adaptation by printers of the merchant's mark of earlier centuries. Its first use in a printed book was in the Psalter by Fust and Schoeffer, 1457; this Psalter was also the first book to be printed in colour.

PRINTING. All printing processes can be placed in one of three main groups: (a) Relief processes, which include all those in which the printing image is sufficiently elevated and isolated from the non-printing areas to permit the printing section to be inked and the ink impressed on the paper or other material without soiling the non-image parts. Newspapers and books are the commonest examples of use of this process. (b) Planographic processes, in which both the image and non-image sections are on a level, or nearly level plane, which would cause

both the sections to accept ink unless suitable restraining methods were used. Lithography is the main example and Collotype (q.v.) would also be placed in this group. (c) Intaglio processes, in which the image is recessed—usually by etching. This group is typified by such names as Gravure, Photogravure (q.v.) and many similar terms.

The story, from the days of copyists to our own time, with all the variety, quality, precision and incredible speed of modern production is one of dogged persistence, individual and collective pioneer effort, and adaptation of the findings and developments of the various crafts and sciences. From the handy craftsman who made his own inks and varnishes, designed and cut his blocks and constantly exercised an almost uncanny gift for improvizing, printing has moved to the condition where the craftsman specializes more and more in less and less, and where the trade supply house provides down to the last ready-made pin and paper fastener and gadget—and beyond.

From hand methods the pendulum has swung to largely mechanized processes and high-speed precision machines. Widespread fear exists that the days of the craftsman are numbered, but this fear is unwarranted: machines evolve, processes come and go, yet the craftsman is supreme although his application has been, and may be further, modified.

A most important feature in the development of the graphic processes is the use which has been made of photography. Since the introduction of the half-tone screen the photomechanical processes have dominated all branches of reproduction in both monochrome and colour.

Colour reproductions tend to use fewer printings, and yet there is a keener demand for critical likeness. The achievements of two, three and four printings at their best are truly remarkable. Photographic colour processes have recently made such progress that real colour photographs are readily available as copy for reproduction by any of the major printing groups. Each process has its own characteristic features as well as its limitations.

As in many other progressive industries, the problems of the printing and allied trades are now investigated by their own Research Association. This Association, known as P.A.T.R.A., was established in 1930. Much valuable research work has been achieved, and more is expected in both short-term and long-term investigational work.

The printing industry has benefited, not only by this specific impact of scientific investigation, but also by the general progress of science. For example, modern engineering practice provides suitable design, speed and efficiency of mechanical equipment; physics, electrical control and photography; metallurgy and electrochemistry, durable metallic printing surfaces; chemistry, inks, paper, solutions, solvents, plastic surfaces and the like. Indeed, the developing of all scientific knowledge contributes to improvement of some branch of printing craft or organization. Conversely, the development and preservation of the sciences, and of all knowledge, are in great measure dependent on the art and practice of printing, which make thought and speech both visible and enduring.

Printing plays a vital part in modern warfare, and experiences new developments in consequence of the special conditions. For example, by means of entirely self-contained mobile Photolitho units, the Army produces, very speedily and under Service conditions, maps of newly surveyed territory and similar urgent or secret matter.

PRINTING INKS. The many printing processes with their wide range of speeds and variety of products, from the urgent newspaper to the choice art reproduction, together with the widely contrasting printing stocks, from high-grade blottings to non-absorbent foil, from flimsy tissue paper to glassine and heavy metal plate, impose a continuous demand on

the ability and research of the manufacturer of printing ink. Appropriate ink is formulated for each general class of work, while specific problems are dealt with by the ink maker as they arise.

Even when correct inks are used, workshop conditions of varying temperature and humidity may cause difficulties. Process, paper and ink should be chosen as a unit to obtain consistently good results, e.g. offset printing requires a paper which is free from fluff and loose particles, and an ink of strong hue-concentration which is not readily affected by contact with water.

Printing ink is essentially an intimate mixture of pigment, vehicle, or liquid base, and compound (and usually drier), which are chosen, balanced and ground to produce a desired effect by a specific process and on a certain class of paper or printing stock. Important as are the choice and balance of materials, the grinding is the critical operation which most affects the working properties of printing inks. The consistency of printing inks may generally be said to vary with the speed of printing; the higher the speed the softer the ink.

Commercially, a printed ink film may be said to be dry when the printed matter is serviceable for the purpose for which it is produced. Unsized or soft-sized papers readily absorb printing ink, and for practical purposes the ink is dry on application. Hard-sized or hard-surfaced papers do not absorb ink, and when they are used drying needs acceleration. On glassine, metal foil and metal plate, drying is in no way assisted by penetration. Further, when inks are superimposed, the first printing or printings must dry in a way which preserves their lifting or trapping qualities, and this calls for correct choice of drier.

Printing inks dry in one or more of three ways: (1) penetration of, or absorption by the stock, (2) oxidation, (3) evaporation. Also, some modern inks have a quick initial setting quality known as thixotropy (q.v.), which facilitates the early handling of printed sheets, and this setting precedes the actual drying. News ink, for example, dries entirely by penetration; inks used on tub-sized papers, or greaseproof and the like, need to be dried by oxidation; gravure and aniline inks dry by evaporation, which in turn may be further accelerated by air current or heat.

The importance of the acceleration of the drying of printing ink is indicated by the remarkable number of patents which have been—and continue to be—taken out to cover this problem. The variety of methods suggested is partly due to different principles by which the drying effect is obtained, e.g. evaporation of the volatile vehicle leaving the solid pigment, as in gravure printing, oxidation and polymerization producing a tough film in the printing of metal sheets and similar unabsorbent materials.

Examples of methods used are: fanning; vibration; radiant heat; ozone; live steam, high-velocity hot, cold and dry air; hot air, moving or stationary; compressed air, electrically or gas-heated printing cylinders; passing of sheets or web over heated surfaces or through bunsen flames. The drying method must be chosen carefully to suit the ink. For example, heat would not be used on a wax-based ink. See ANILINE INK, COLLOTYPE INKS, DOUBLE-TONE INK, GLOSS INK, HALF-TONE INK, JOB INKS, LITHOGRAPHIC OFFSET INKS, NEWS INK, TIN-PRINTING INKS, WATER-COLOUR INK, WEB-PRESS INKS and WET-PRINTING PROCESS INKS.

PRINTING MACHINES. Machines which do the actual job of printing, more familiarly known as presses. They may be divided roughly into three types; (1) platen, (2) cylinder and (3) rotary.

The *platen* machine has a plate or platen on which the packing and make-ready (q.v.) are fastened, and on this the sheet to be printed is held in guides and pressed against the forme, which is held vertically. The *cylinder* type makes use of a cylinder

to press the sheet against the type face, which is supported on a flat-bed. On the *rotary* press the type face, cast in half-cylinders which are joined over a roller, revolves and prints either or both sides of a sheet or roll of paper. All newspaper printing presses are reel-fed when of the rotary type.

There are many sub-divisions under these three heads, with differing types too numerous to mention, but the underlying principles are the same. In nearly all machines the inking is done by means of a series of rollers, which carry the ink from a trough or duct and spread it evenly over the type face. Sometimes, however, there is a slab over which the ink is spread before being carried to the type.

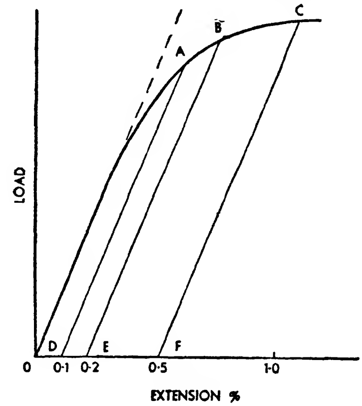
PROCESS ANNEALING. A process used in the sheet-metal and wire industries for softening low-carbon steel which has been previously hardened by cold-rolling or drawing operations. The steel is heated at a temperature within the range 550 to 650 deg. C., generally nearer the upper limit, when the distorted and hardened crystals of ferrite, of which the steel is largely composed, recrystallize rapidly, so reducing the steel to its softest possible condition.

PRODUCER GAS, see Fuels.

PROFILE DRAG, see Drag.

PROOF STRESS. The load, measured in tons per sq. in., which, in a tensile test, will produce a permanent extension equal to a definite percentage of the gauge length—e.g. 0·1, 0·2, or 0·5 per cent. It is important to know to what definite stress a material can be safely loaded without much permanent extension taking place.

Mild steel shows an unmistakable yield point (q.v.), but light alloys and many other materials do not. It is for these that a proof stress is specified.



Load-extension diagram from which proof stress may be determined.

Accurate determination of proof stress is made from a load-extension diagram such as is shown in the illustration. Extension of the test-piece with load occurs along the line OABC. On removing the load at any particular value, for example at A, elastic contraction takes place along the line AD, the permanent extension being indicated by the intercept OD.

PROPELLER. A device for converting the power of the engine into thrust to propel an aircraft through the air. It does this by accelerating the air as it passes through its disk, in much the same way that a wing deflects or accelerates the air within the influence of its span, downwards to produce lift.

A propeller consists of two or more blades, attached to a hub into which the engine shaft fits, as shown in Fig. 1. The maximum number of blades visualized at the present time is eight, the most common number being two or three. The blades are of

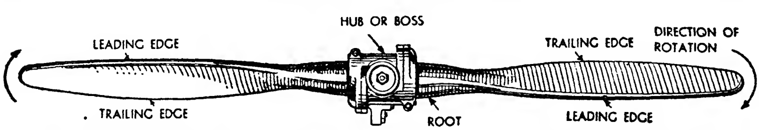


Fig. 1. Diagram indicating main terms used in connexion with aircraft propellers.

aerofoil section (q.v.), normally of the type with a flat under-surface. They are twisted, as is shown in Fig. 2, the sections being at progressively greater angles of incidence to the propeller disk towards the tip, so that each section meets the air at about the same angle of attack (q.v.), as shown in Fig. 3. Actually, sections near the tip are at a smaller angle of attack than those at the root to allow for their higher speed due to being at a greater distance from the centre. When the propeller is rotated each blade acts rather like an aeroplane wing, the lift being equivalent to the thrust, and the drag representing the work the engine has to do to turn the propeller.

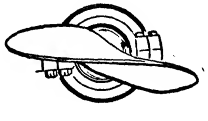


Fig. 2. Foreshortened view of propeller showing twist of blade.

The propeller, as its other name of airscrew suggests, resembles an ordinary screw inasmuch as it rotates about an axis, while at the same time moving forward along that axis. Pitch is defined as the advance per revolution and the advance per revolution under any given conditions is the mean effective pitch under those conditions. For the particular case of the propeller developing zero thrust, the mean effective pitch is called the experimental mean pitch. The geometric pitch is the advance per revolution of any section of the blade along a helical path whose angle is equal to the blade angle. In practice many propellers are designed so that the geometric pitch is constant along the blade, but if this is not so, the geometric mean pitch is defined as the pitch of a section at 0·7 or 0·75 of the radius from the centre.

At one time, before the advent of supercharged engines, and while speeds were still low, efficient propellers could be designed with fixed blades, and even after supercharged engines were introduced it was still possible to make a propeller which offered a fair compromise. Today however, with engines supercharged to operate at great altitudes, and with a speed of over 400 m.p.h., it is necessary on all but light aircraft to be able to adjust the setting of the blades for the various conditions of flight, so that the engine may run at its correct number of revolutions per minute and deliver its full power.

A propeller in which the blades can be rotated to vary the angle of attack or pitch is called a controllable-pitch propeller. Most controllable-pitch propellers are now fitted with a governor so that the pitch may be adjusted automatically to maintain the revolutions per minute at any desired value, however the power or speed of the aeroplane is varied.

The power that a propeller can usefully absorb depends on its diameter, its rate of rotation and blade area. There is, however, a limit to the revolutions per minute which may be used, for, as the speed of the tips of the blades through the air approaches the speed of sound, the efficiency falls off very rapidly. There

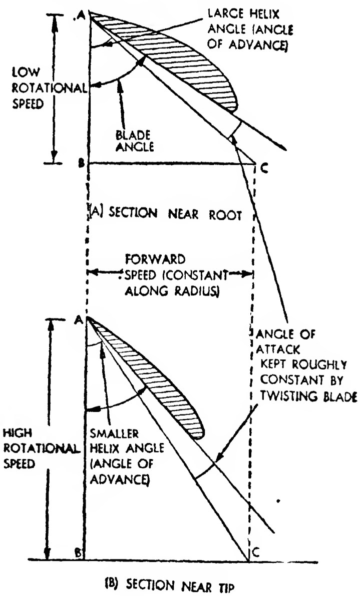


Fig. 3. Sections of propeller blade showing how angle of advance BAC varies between root and tip of blade.

are generally practical considerations which limit the diameter, such as ground clearance etc. When high powers have to be absorbed by a given diameter the only thing that can be done is to increase the blade area or solidity. This can be done by increasing either the width of the blades, or their number; the latter is more efficient.

Propellers of more than four blades are frequently made contra-rotating; that is to say, one set of blades rotates in one direction, and a second set, behind the first, rotates in the opposite direction. A contra-rotating propeller is more efficient than a single rotating one of an equal number of blades. Other advantages of contra rotation are the absence of torque effects and slipstream rotation, which leads to the elimination of swing during take-off, and a general all-round improvement in the flying qualities of the aircraft.

In order to increase the performance when flying with one or more engines dead, controllable-pitch propellers on multi-engined aircraft are made to feather. A propeller windmilling with the blades set at the normal operating angle has a very high drag; this is reduced very considerably when the blades are turned edge to wind, or feathered. This also stops rotation, which might cause extensive damage to the faulty engine.

When the propeller is in front of the engine it is called a tractor, and when it is behind, a pusher.

It is of primary importance that aircraft propellers should be perfectly balanced, otherwise considerable vibration will result. For this reason, all components of a propeller are carefully tested, both during assembly and on completion.

PROPELLER COEFFICIENTS. The three primary propeller coefficients are those of *thrust*, *torque* and *power*. They are non-dimensional and, as their name suggests, relate the thrust exerted by a propeller, the torque required to turn it, and the power it absorbs, to its diameter, rate of rotation and the atmospheric density at any given value of the advance ratio J or $\frac{V}{nD}$ which, for a propeller, is what angle of attack is for a wing.

If we let

T = thrust in lb.
Q = torque in lb. ft.
P = power in ft. lb./min.
n = revolutions per sec.
D = diameter in ft.
v = forward speed in ft./sec.
ρ = air density in slugs/cu.ft.

Then

$T = k_T \rho n^2 D^4$
$Q = k_Q \rho n^2 D^5$
$P = k_P \rho n^3 D^5$

where k_T, k_Q and k_P are the thrust, torque and power coefficients respectively.

The coefficients vary with the advance ratio, but each particular value is constant for a family of geometrically similar propellers. Thus, for example, from a set of values of the thrust coefficient for various advance ratios determined for a model propeller in a wind tunnel, we are able to predict the thrust that would be exerted by its full-scale counterpart under any conditions. This holds only for a fixed-pitch propeller, or for a controllable-pitch propeller at a set blade-angle.

The advance ratio being also dimensionless, to produce alternative forms it is possible to multiply any of the coefficients by it as many times as required. One such form, originating in the U.S.A., is in general use and is called the speed/power coefficient. It is obtained by multiplying the inverse fifth root of the power coefficient by J to give

$$Cs = \frac{J}{k_P^{\frac{1}{5}}} = \frac{v\rho^{\frac{1}{5}}}{P^{\frac{1}{5}} n^{\frac{2}{5}}}$$

Its utility lies in the fact that it does not contain the diameter, so that when plotted against the advance ratio and the efficiency for various blade settings it can be used to select the optimum diameter for given design conditions of speed, altitude, power and revolution per minute.

The efficiency of a propeller in terms of its coefficients is given by

$$\eta = \frac{1}{2\pi} \times \frac{V}{nD} \times \frac{CT}{CQ}$$

PROTECTIVE GEAR. In any system of electrical circuits or apparatus, it is necessary to make provision for isolating faulty components, both to reduce the damage to the system itself and to remove conditions dangerous to life and property. This is the function of protective gear and its associated apparatus. It is called upon to operate when the current in any place is excessive, when the current follows paths other than those prescribed for it and, in certain cases, when the supply fails, or when power flows the wrong way.

The simplest apparatus is the well-known fuse widely used in domestic installations. While it is adequate for its job, it is not suitable for use in power systems, except in modified forms (see FUSE).

The principal disadvantages of the simple fuse are that it is somewhat erratic in performance, it deteriorates with age, it is fiddling and slow to replace and cannot be set to close limits, while for large currents it acts instantaneously.

It may not be obvious why the last feature is a disadvantage, but consideration of the desirable features of a protective system will show why this is so.

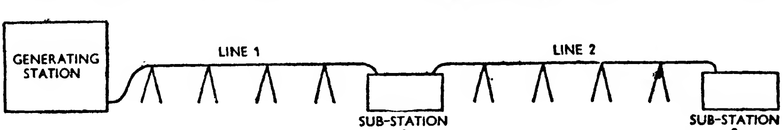
Suppose that the apparatus to be protected is a length of three-phase transmission line. Two things may happen to it; there may be what is known as a phase fault, which is a short-circuit between two of the lines, or there may be an earth fault, that is, one of the lines may break or otherwise become earthed.

The phase fault may be detected by means of relays and current transformers (q.v.) at the sending end. The excessive current causes the relay to operate and this, in turn, trips the circuit-breaker and so cuts off the supply to the line. The earth fault may be detected by means of a relay so connected that it operates when the currents in the line are not balanced. Since the vector sum of the currents is normally nothing (see ALTERNATING CURRENT) an extra current flowing in only one of the wires must upset this condition.

Now suppose that there is a sub-station at the end of the line and then another length of transmission line to another sub-station, as indicated in Fig. 1.

If a short-circuit should occur on line 2, then, as far as line 1 is concerned, it is a through-fault and the relays at the generating station will operate as well as those on the outgoing side of sub-station 1. The result is that the whole system is deprived of supply, both the faulty line 2 and the healthy line 1 being disconnected. This situation is obviously undesirable; the protective system must be able, therefore, to discriminate between faults which occur on line 1 and those on line 2. To achieve this, the relays are arranged so that they do not operate instantly but after a time-delay, which is graduated according to the distance between the relay and the generating station. The relays nearest the source of supply have the longest time-lags.

With this arrangement, the relays at sub-station 1 operate before those at the generating station and if they



PROTECTIVE GEAR FOR ELECTRICAL CIRCUITS.

Fig. 1. This simplified transmission scheme uses radial feeders serving sub-stations in sequence. Any fault which occurs in line 1 renders the whole system dead.

should by any chance fail, the latter give back-up protection.

Many relays have what is known as inverse time-lag, similar to that of a fuse. This simply means that a slight overload causes operation in a relatively long time, whereas a large overload causes instant operation.

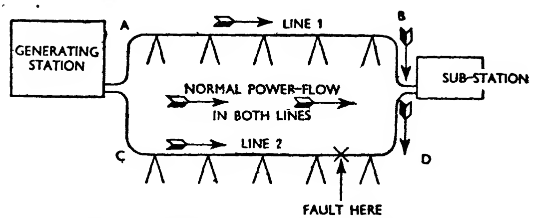


Fig. 2. Parallel feeders to the same sub-station permit supply to be maintained with one of the lines out of action. The text explains how a fault is cleared without the inconvenience occasioned by interruption of supply.

There is thus a danger that both sets of relays might operate together in the event of a short-circuit, and to counteract this the relays are designed to have a definite minimum time of operation, no matter how heavy the current.

Another way of obtaining discrimination, which does not require any time-delays, is to use relays at both ends of the line connected by means of pilot wires (q.v.). Under normal conditions the current entering line 1 is equal to the current leaving it, so that similar current transformers at each end produce equal voltages. If these current transformers are connected by pilot wires no current flows (see MERZ-PRICE SYSTEM). In the event of a fault on line 2 the above condition still holds, but a fault on line 1 makes the voltages no longer equal and the resulting current operates the relays.

Discrimination without pilot wires is obtained by using distance protection. In these systems the relay, as it were, measures the distance between itself and the fault, and the longer that distance the greater is the time-delay. To secure this, the time of operation is made to depend upon either the impedance or the reactance of the length of line up to the fault.

There are a number of other ways of achieving the above results, some using pilot wires and some not, but space does not permit of their description here.

A wattmeter tries to read backwards when the current or voltage polarity is reversed, that is, when the direction of power flow reverses. The wattmeter principle is used in reverse-power relays which operate only when the flow of power is the wrong way. They may be combined with an over-current relay so that not only must the power be the wrong way but the current must be excessive as well before they operate.

A generating station connected to a sub-station by two lines in parallel is shown in Fig. 2. Relays are installed at the points marked A, B, C and D. Those at A and C are over-current relays, while those at B and D are reverse-power relays. There are circuit-breakers at A, B, C and D, each operated by its own relay.

Suppose a fault occurs at the point marked on the diagram. Power is fed to it along both lines, in the direction marked by the arrows, so that at D the power direction is opposite to normal and the circuit-breaker at D is opened. When this happens the conditions in line 1 return to normal. This line is not disconnected, although the current was excessive, because the relay at B does not try to operate, while that at A is subject to a time-lag. The whole of the fault current is now fed through line 2 and the relay at C operates and causes the circuit-breaker at C to open. The faulty line is then isolated at both ends, while supply to the sub-station is maintained through line 1.

In the case of a ring main (q.v.) the problem is more complicated because the power may normally flow in either direction, except in those feeders which are adjacent to the

generating station. The protection can still be obtained by using reverse-power relays fitted with time-delays.

The protection of machinery forms a separate branch of the subject, though some of the methods described are also applicable to machines. A simple starter contains an overload device to disconnect the machine when the current is excessive, either because of a fault in the motor or because of misuse. It has also a no-volt release to switch the motor off if the supply fails, or if, as in some cases, the field is accidentally broken. These devices together give all the protection that is needed by most motors.

Generators and large motors are expensive enough to justify the provision of further protective devices. There may be equipment to detect overheating in the windings and bearings and failure of cooling-air supply, while provision may also be made to disconnect a generator if it begins to run as a motor from other parallel machines.

Machines which start and run unattended require yet more protection; the gear installed in an automatic rotary-convertor sub-station, for example, is fascinating in its complexity and ingenuity.

The ideal protective system should be reliable, cheap, rapid in operation, and should show perfect discrimination. It should be flexible so that it may be used on any machine or circuit and should be so designed that no adjustment is required when changes or extensions are made elsewhere on the system. Finally it should be self-testing, so that it calls attention to itself when it goes wrong.

PROTEINS. Essential constituents of every animal and vegetable cell. They are all constructed on this plan: a chain of groups of CO, NH and CH, to which are attached sundry groups, usually rather complex.

PROTOACTINIUM (Pa). Atomic no. 91; atomic wt. 230·6. A metal somewhat resembling tantalum (q.v.); it is radioactive and gradually turns into actinium. An oxide, Pa_2O_5, and a chloride, $PaCl_5$, have been prepared.

PROTON. The unit left when, for example, a hydrogen atom loses its electron; unit of positive electricity. It is probably one of the units from which all forms of matter are built.

PROTRACTOR. An instrument used in drawing offices for setting out one line at a given inclination to another, or for measuring the angle between two lines. It is usually semi-circular in form, made of celluloid or some transparent plastic material and graduated around the curved edge in degrees.

Large-sized protractors may be graduated in half, or even quarter, degrees. Some types are supplied with a swinging arm which travels around the fixed centre and can be clamped at any angle; the arm may also carry a vernier scale which enables readings to be made to within a small fraction of a degree (say $\frac{1}{12}$ or $\frac{1}{20}$). In machine shops another form of protractor—the bevel-gauge—is in general use by machinists and tool-room workers. It is provided with a solid base or stock, to which an adjustable blade (or straight edge) can be set at any desired angle. The instrument usually has a scale carrying degree graduations.

PRUSSIAN BLUE. A compound of iron, carbon and nitrogen; the main blue used in oil paint, it is characterized by the deep reddish-blue tone. No other blue has the same depth; when dry it has a bronzy appearance. It is very difficult to grind in oil; to overcome this defect, during the process of its manufacture it may be incorporated with barytes (q.v.) and is then known as *Brunswick*, *Berlin* or *Paris* blue.

The chief objection to the use of these is that when incorporated in mixed paint, the barytes may settle out. Prussian and kindred blues are very strong stainers but are transparent when ground in oil. They may not be used with lime or other alkalis and fade slightly in strong sunlight. *Antwerp* blue, similar in character to Prussian blue, has the iron replaced by zinc in its composition; both, in combination with lead or zinc chromes and extenders, form the

bright greens used as pigments in oil paints.

PTERODACTYL. A form of aeroplane originated by Prof. G. T. R. Hill, in which directional and longitudinal control is obtained, not by the normal type of tail or empennage (q.v.), but by what are called controllers, similar to ailerons, at the tips of tapered and heavily swept-back wings. The controllers serve both for longitudinal and lateral control, and for directional control; some models have rudders at the wing tips, while others rely on inherent stability.

While none of the machines built to date have got beyond the prototype stage, there would appear to be a future for the type when associated with jet propulsion, or in very large sizes in which the wing can be made deep enough to accommodate the load, incorporating, at the same time, low-drag wing sections and pusher propellers.

PUDDLED BAR, see WROUGHT-IRON.

PULLEY STILES, see CASED WINDOW FRAMES.

PULPS, see PAPERHANGINGS.

PUNCH. The cutting part of a press tool which enters the opening of the die section. It is usually the top member attached to the ram of the press, but in inverted press tools it may occasionally be the bottom member. Punches may be held in the holder in many ways; a single punch may enter and be clamped direct in the end of the ram, while multiple or gang operations necessitate several punches fixed in a punch-plate in their proper sequence, the plate being then bolted to the ram. Dove-tail slots with taper wedges are an alternative to holding by set screws, while a tapered hole location is useful for holding small piercing punches.

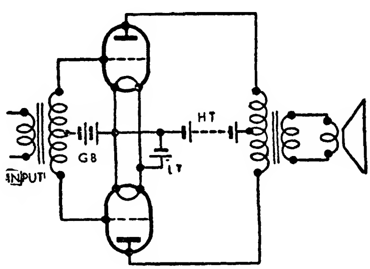
PUNCHING MACHINE, see POWER PRESS.

PUSH-BUTTON TUNING. A system of tuning a radio receiver to any one of a number of pre-selected stations by means of pressing the appropriate button instead of by rotating a conventional tuning knob.

There are three basic ways in which push-button tuning may operate: (1) systems in which operating a button disconnects the ordinary tuning system and switches in pretuned-circuit elements, (2) arrangements in which pressing a button mechanically rotates the ordinary control spindle to the required position and (3) a system similar to (2) except that the button controls an electric motor which drives the tuning spindle. This last method is sometimes called motor tuning.

PUSHER, see PROPELLER.

PUSH-PULL. A system of amplification employing two amplifying valves working 180 deg. out of phase. The input to the pair is split by means of a suitable transformer or other circuit arrangement, the output being similarly combined. This arrangement offers many advantages, the chief of which is a reduction in distortion owing to the cancellation of harmonics in the common output circuit of a correctly matched and balanced push-pull amplifier.



Showing the basic arrangement of a push-pull circuit. The input is divided by means of a transformer, thus supplying the grids of the valves with signals 180 deg. out of phase. The separate anode currents are combined in the output transformer.

With this system, it is possible, particularly in audio-frequency work, to achieve higher anode efficiencies than with a single valve, and such an arrangement is extensively used in high-power amplifiers.

PUSH ROD. On engines, a rod used to transmit reciprocating motion from

one working part to another. In internal-combustion engines having overhead valves, push rods, with their lower ends in contact with cams on the camshaft, are used to operate the valve rockers.

PUTTY. A soft, pliable substance, consisting of a mixture of whiting and linseed oil, used for fixing panes of glass in window frames and for stopping cracks and holes in wood prior to applying paint.

PYINKADO, see IRONWOOD.

PYROLUSITE, see MANGANESE.

PYROMETER. An instrument for measuring temperatures beyond the upper limit of the ordinary mercury-in-glass thermometer.

As the name implies, *thermo-electric* pyrometers make use of the thermo-electric effect. If two wires of different metals are joined at their ends, and one junction is heated, an electromotive force is developed, as shown by a sensitive millivoltmeter included in the circuit. The electromotive force is proportional to the temperature difference between the hot and cold junctions. If the cold junction is maintained at a constant temperature, and the hot junction at various *known* temperatures, a graph may be plotted showing temperature against electromotive force. The instrument is now calibrated, and may be used as a pyrometer to measure unknown temperatures. Thermocouple materials include iron-constantan for temperatures up to 750 deg C.; chromel-alumel for temperatures up to 1200 deg. C.; platinum platinum-rhodium for temperatures up to 1450 deg. C.

Thermo-electric pyrometers incorporate methods of compensating for variations in the cold-junction temperature. They are sensitive and reliable, but require regular checking. Heat treatment furnaces are fitted with built-in thermo-electric pyrometers, and temperature-recording and controlling equipment is frequently installed. The thermo-electric pyrometer is largely responsible for the precision and accuracy of modern heat-treatment operations.

Total-radiation pyrometers are used for high temperatures, where contact of the pyrometer with the hot object is not desirable. The total energy radiated by a "black body" (i.e. one which is a perfect radiator) is directly related to its temperature. Many industrial furnaces are approximately "black bodies", in the sense that the energy radiated from the interior may be used as a measure of the temperature.

A telescope is sighted upon the hot object and the radiation is focused on a small thermo-couple, which is connected to a sensitive electrical indicator graduated in degrees Centigrade. The temperature may thus be read-off directly.

Much correction is necessary when total-radiation pyrometers are used to measure the temperature of molten metals etc., which are not perfect radiators.

Optical pyrometers differ from the total-radiation type in that only part of the emitted radiation is used—as a rule the red portion of the visible-light range. In the "disappearing filament" pyrometer, the hot body is viewed through a telescope, and its brightness compared with that of a standard lamp fixed inside the telescope. The lamp filament is seen superimposed over the image of the hot body, and by means of a variable resistance the current in the filament is adjusted until the brightness of its tip is the same as that of the hot body. At this point the filament disappears, since it merges into the image of the hot body. The temperature corresponding to this point may be read-off directly.

The three types of pyrometer described above are those commonly used in the industrial treatment of metals. Other types are made, depending on (*a*) the increase in the electrical resistance of platinum with rise of temperature; (*b*) the expansion of mercury in a steel bulb, connected by capillary tubing to a pressure gauge graduated for temperature. The latter type is frequently used in the artificial ageing of light alloys.

"Q." In radio, a factor indicating the goodness of a tuning coil. It is defined as the ratio of the coil's reactance to its effective resistance.

Numerically, it is $\frac{2\pi fL}{R}$, where f is the frequency in cycles per second, L the inductance of the coil in henrys and R its effective resistance in ohms. The term is also applied to a tuned circuit at resonance when Q is given by $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$, where R is the effective series resistance, L the inductance in henrys and C the capacitance in farads.

In a series-resonant circuit, it may also be defined as the ratio of voltage across the coil or condenser to supply voltage; in a parallel resonant circuit it is the ratio of circulating current to feed current.

Q.P.P., see Quiescent Push-Pull.

QUADRATURE. An electrical term which denotes a phase difference (q.v.) of 90 deg.

QUARTER-PHASE SYSTEM. Synonym for two-phase system (q.v.).

QUARTZ. A crystalline form of silicon dioxide, SiO_2. A very common mineral, the chief constituent of sandstone and an important constituent of many other rocks, e.g. granite. It has a density of 2·65, and a hardness of 7. It melts at about 1650 deg. C. Vitreosil, a fused variety of quartz, is used for making chemical vessels. Amethyst is a violet-coloured quartz, Cairngorm a yellowish variety. In quartz each silicon atom is surrounded by four oxygen atoms, and each oxygen atom is surrounded by four silicon atoms.

Crystals of quartz rotate polarized light, and there are two varieties of the crystals, one of which rotates the light to the right and the other to the left.

Quartz may be softened by great heat, and can then be spun into very thin but strong fibres used for suspending galvanometer needles and for other delicate electrical purposes.

Quartz crystals have the property of producing electric charges when they are compressed or stretched; also if the crystal is subjected to an alternating electric force a vibration is set up in it. This property is made use of in radio communication. See Quartz Crystal and Silicon.

QUARTZ CRYSTAL. In radio, a term usually applied to a slice specially cut from a natural quartz crystal and possessing piezo-electric properties. Such a crystal is a mechanical vibrator which is electrically equivalent to a high-Q series resonant circuit, and is often used where frequency stability is essential, e.g. for controlling or fixing the frequency of radio transmitters. The resonant frequency of a quartz crystal is determined by its shape, thickness, length and cut.

Natural quartz crystals are usually hexagonal prisms terminated at one or both ends by a six-sided pyramid. A line joining the vertices of these pyramids and perpendicular to the plane of the hexagonal cross-section is known as the optical or Z-axis. The electrical or X-axes are in a plane at right-angles to the Z axis and pass through opposite corners of the hexagon; they are thus three in number. The three mechanical or Y-axes are in the same plane but perpendicular to the sides of the hexagon.

For radio work, slices are cut from a natural crystal at various angles to its main axes and accordingly have different properties. Basic cuts are known as X and Y because of their respective axes, but specialized cuts are more generally used in practice. See Piezo-Electric.

QUEEN CLOSER, see Closer.

QUENCHING. A process of rapidly cooling a metal or alloy from an elevated temperature by immersion in a relatively cold liquid. The

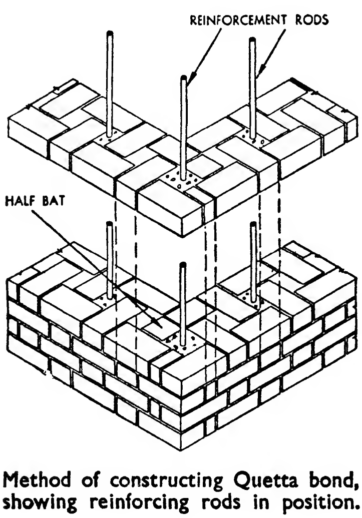
purpose is generally to prevent or retard a structural change that would otherwise occur on cooling at a normal rate. Usually with an alloy, the process results in a considerable increase in strength and a reduction in ductility.

The effect is immediate in the case of steel but may be delayed in the case of certain aluminium alloys. Indeed, such alloys may be put in the softest possible state by quenching, hardening finally occurring, either after a considerable lapse of time, or rapidly if the alloy is reheated at a relatively low temperature.

Quenching naturally produces great differences in temperature between various parts of the same article. Different parts may thus contract at different rates, so setting up contraction stresses which in turn produce distortion, and possibly cracking, of the article.

In order to minimize these effects, a medium giving the slowest possible rate of cooling, consistent with obtaining the desired results, must always be used. Quenching media in common use, arranged in order of decreasing cooling rates, are: brine, water, oil and molten salts.

QUETTA BOND. A special arrangement of bricks in which vertical cavities are formed in the thickness of a wall for the accommodation of steel reinforcing bars.



Method of constructing Quetta bond, showing reinforcing rods in position.

The inclusion of reinforcement not only adds strength to the brickwork but also provides additional resistance to shock and lateral pressure. The reinforcing rods are placed in position before the wall is built, and the cavities are filled with concrete, thus forming a series of vertical reinforced concrete posts throughout the length and height of the wall. See REINFORCED BRICKWORK.

QUICKLIME. Calcium oxide produced by burning chalk or limestone (calcium carbonate—CaO_3) in a kiln to a temperature of about 936 deg. C. In the process the carbon dioxide is driven off, leaving calcium oxide (CaO).

Quicklime is highly caustic and possesses an affinity for water. Quicklimes must be slaked or hydrated before being used for any purpose in building construction. See CALCIUM.

QUICKSILVER, see MERCURY.

QUIESCENT PUSH-PULL. An amplification system in radio practice using two valves in push-pull (q.v.), so that in the absence of a signal their combined anode current is almost zero, owing to a large negative bias on their grids. So biased, the valves will each amplify only during the time when their grids are swung in the positive direction, the individual anode currents rising in proportion to the signal voltage applied. The type of distortion so produced will automatically vanish with two valves in push-pull.

In amplifying ordinary broadcast programmes, the full output of the valves is required for only brief moments during volume peaks and thus, with this arrangement, it is possible to reduce the average anode current. Accordingly, Q.P.P. is often used in battery-operated receivers for reasons of economy.

QUININE. A well-known alkaloid and drug. Alkaloids are compounds of carbon, hydrogen, oxygen and nitrogen found in plants; some of them can be artificially synthesized. Quinine, $C_{20}H_{24}O_2N_2$, is a tonic, often used to

cure neuralgia, colds, influenza and especially malaria.

QUINONE ($C_6H_4O_2$). A yellow, crystalline solid melting at 115·7 deg. C., soluble in alcohol, benzene and hot water. It is made by the oxidation of aniline, and is used in the manufacture of sundry dyestuffs.

QUOIN. The external angle of a wall. The angle may be square, obtuse, or acute. The walling material forming the quoin may be classified as "quoin stone", or "quoin brick", etc. Quoin stones are usually of larger dimensions than the surrounding stones, and are arranged to bond with the other stones in the wall in each direction. The faces of the stones may be left plain or specially dressed to a particular architectural treatment.

RADAR. A term, originating in U.S.A., meaning "radio detecting and ranging" and being used instead of radiolocation (q.v.).

RADIAL ENGINE. A form of aircraft engine in which the cylinders are disposed radially round a common crankshaft like the spokes of a wheel round the hub. This arrangement is made in order to secure a light, compact engine. All radial engines are air cooled, and they have any number of cylinders per bank up to a maximum of nine, while there may be one, two or more banks, each bank operating on a single throw of the crankshaft. The most favoured arrangements at the present time are nine-cylinder single-bank, and fourteen- and eighteen-cylinder two-bank.

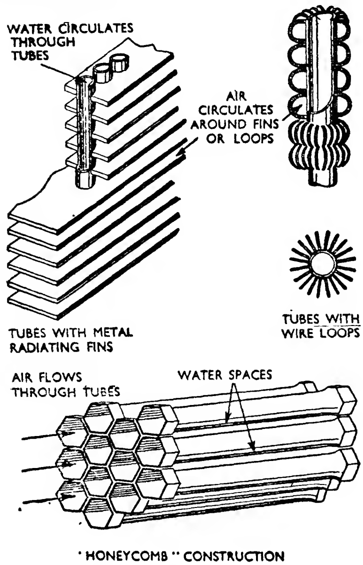
RADIATION. The transmission of energy through space by means of electromagnetic waves. Among the various kinds of radiation are the α (or positive) rays, β-rays (cathode rays or electrons), γ-rays (X-rays of very short wavelength emitted by radio-active substances), heat, light, electrical and cosmic rays; the last are rays of very short wavelength reaching the earth at all times with equal intensity. It is supposed that they are caused by the conversion of matter into energy in stellar space.

The accompanying table shows some of the principal wavelengths.

RADIATION	WAVELENGTH	
Long electric waves	More than 100	kilometres
Long radio waves	About 20	
Short broadcasting	„ 20 metres	
Long infra-red waves	„ 0·03 millimetres	
Short infra-red waves	„ 7700	Ångström units
Visible spectrum:		
Red	„ 7000	
Orange	„ 6000	
Yellow	„ 5500	
Green	„ 5000	
Blue	„ 4500	
Violet	„ 4100	
Ultra-violet	3900 to 130	
X-rays	1000 to 0·03	
γ-rays	1·4 to 0·01	
Cosmic rays	0·0008 to 0·00003	

RADIATOR (Aero. Engineering), see COOLING.

RADIATOR (Auto. Engineering). A device used, with internal-com-



Three types of radiator construction showing passages provided to ensure adequate circulation of air and water.

bustion engines having the pump-assisted or thermo-syphon cooling system, to disperse the heat generated in the cylinders. A radiator usually consists of thin tubes, or passages, of honeycomb shape through which the water from the cylinder block and header tank passes, air being forced across the tubes by the motion of the vehicle and assisted by means of a fan mounted behind the radiator and driven by a belt on a pulley on the end of the crankshaft.

To increase the area of the tubes in contact with the atmosphere, metal fins or small wire loops are fitted to the tubes, as shown in the accompanying illustration. In the honeycomb type of radiator the water flows through the small space between thin tubes soldered together at their edges. The completed radiator gets its name from the appearance of a honeycomb which it presents from the front or rear.

With this system of cooling it is essential that the outlet pipe from the cylinder head should have an easy slope up to the radiator so that no obstruction is caused. For the same reason a good slope up from the bottom of the radiator to the cylinder water-jackets is necessary. Where this is not possible, however, circulation is assisted, or, in some instances, controlled entirely by a water pump, usually of the centrifugal vane type. See COOLING.

RADIATOR (Elec. Engineering). A coil of wire heated by an electric current on the principle of resistance (q.v.). The wire coils can be backed either by some non-conducting material, such as asbestos, or by a mirror-like concave surface to concentrate the rays of heat.

RADIATOR (Plumbing). A heating unit. Hot-water radiators are usually in the form of a coil of pipes which are flattened to give the greatest possible heating surface in contact with the air. A valve provides a means of regulating the flow, and consequently the temperature. Gas radiators have a burner at the base of a vertical tube and work on the hot-air principle. See CENTRAL HEATING.

RADICALS. Groups of atoms that remain attached together through a series of chemical changes. Among the common radicals are ammonium, NH_4—; methyl, CH_3—; ethyl, C_2H_5—; and phenyl, C_6H_5—; some radicals are of such common occurrence that they are treated almost as atoms and are given symbols such as Am, Me, Et and so on.

RADIO ACTIVITY. The spontaneous breaking-up of an atom by the loss of an α particle or an electron, thus forming a new element of lower atomic weight. This occurs only with elements with high atomic weights, for instance radium, actinium, thorium and uranium.

It is possible to bombard many elements by small particles, especially α particles, protons, deuterons, or neutrons, thus disintegrating the elements so as to convert a portion of them into a different element. It is possible, for example, by bombarding uranium with neutrons to form atoms of lower atomic weight, with the

liberation of vast amounts of energy. This is the basis of the so-called atomic bomb.

RADIO BEACON. A radio transmitter which continuously radiates a known identification signal for direction-finding purposes. Ships and aircraft are able to take bearings on two or more of such beacons and thus determine their own position.

Rotating beacons make use of a special aerial system with a well-defined minimum of radiation in one direction. The whole aerial system is rotated at a constant speed, such that one complete revolution is made in a known time, usually one minute. At the moment when the minimum of radiation is directed to the north, a marker signal, in the form of a "dash", is radiated from a non-directional aerial. The signals from such a beacon can be used by ships for providing bearing information by starting a stop-watch when the marker signal is received and stopping it when the signal heard is at a minimum. The elapsed time and knowledge of the characteristics of the beacon enable the bearing to be calculated.

Since no special apparatus is required at the receiver and little skill is required to use the system, it is very convenient for small ships in which elaborate direction-finding equipment is not installed.

RADIO FREQUENCY (R.F.). A term applied to electrical oscillations of very high frequency, in particular to those frequencies used in radio transmission.

RADIO GRAMOPHONE. A radio receiver incorporating a turntable, pick-up and other apparatus necessary for the electrical reproduction of gramophone records. The output from the pick-up is amplified by the audio-frequency equipment of the radio set and passed to the loud-speaker in the usual way. See GRAMOPHONE PICK-UP.

RADIOLOCATION. A system of determining the position of an object, fixed or moving, by radio waves. It differs from ordinary direction-finding in that no co-operation whatsoever is required from the object being detected and that object need not itself be equipped with radio apparatus. It has many applications, the chief of which is, at present, the location of aircraft or ships in conditions of complete darkness or poor visibility.

Towards the end of last century, Hertz demonstrated that radio waves could be reflected from metallic sheets and from the discontinuity or boundary between two media; in fact, he showed that they behave almost exactly like the more familiar light waves. Modern radiolocation equipment, often referred to as *radar*, consists essentially of a transmitter and its associated receiver. The transmitter radiates waves in short bursts or pulses of regular repetition frequency and the time taken for them to return to the receiver, after being reflected by the aircraft, as suggested by Fig. 1, is determined.

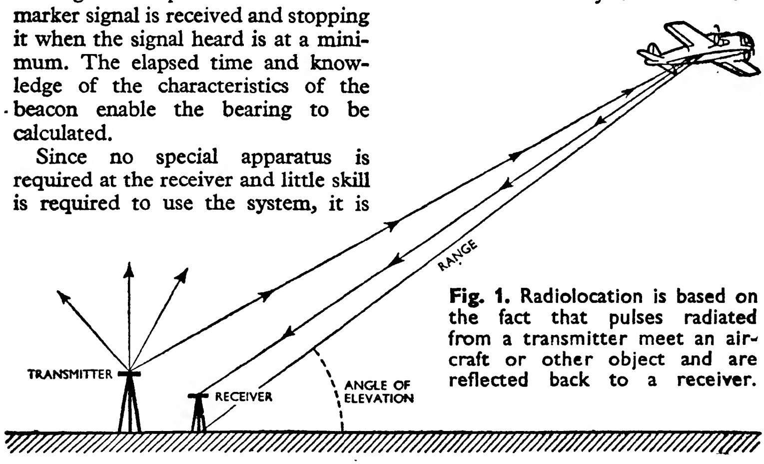


Fig. 1. Radiolocation is based on the fact that pulses radiated from a transmitter meet an aircraft or other object and are reflected back to a receiver.

The complete process is briefly as follows: A pulse is sent out by the transmitter, and simultaneously a suitable time-base voltage is applied to the horizontal deflecting plates of a cathode-ray tube at the receiver. This process is repeated indefinitely, the time-base circuit being synchronized with the pulse generator at the transmitter. Thus, as a pulse is going out into space, the spot on the cathode-ray tube moves from left to right, until, after a fixed time, it returns to the extreme left to start off again in synchronism with the next transmitted pulse. The received pulse, after amplification and rectification, is applied to the vertical deflection plates of the cathode-ray tube, where a "pip" will be seen (Fig. 2).

It is known that radio waves travel approximately 300,000,000 metres, or about 186,000 miles, per second and thus the time base can be graduated in kilometres or thousands of yards. This gives the *range*. Additional information, namely the direction of arrival of the received waves, both in the vertical and horizontal planes, is necessary to determine the actual *position*. This can be obtained by observing the angle of elevation and the bearing or azimuth, using the directional properties of the receiving aerial. Because of their propagation characteristics, very short waves are used for radiolocation.

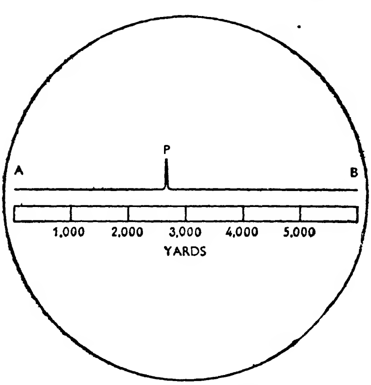


Fig. 2. When a pulse is radiated, the spot starts at A and moves across the screen to B; whilst on its way a "pip", shown at P, is received. Time base is provided with a range scale.

There are more complicated developments of radiolocation than the simple system described above, but the same fundamental principle is employed.

RADIO RECEIVER. A device sensitive to electromagnetic waves of certain lengths, and capable of transforming them into electric currents which are then made to produce sound, or light (television).

The functions of a radio receiver may be divided into four main sections: (1) Selection of the required programme, i.e. frequency or band of frequencies, from all the signals which could be received. This is accomplished by means of tuning circuits and the degree of ability of such circuits in this connexion is known as *selectivity*. (2) Radio-frequency amplification, which consists of a system of magnifying the minute signal before demodulation. Some receivers with but little of such amplification can handle only the more powerful local transmitters, while others, provided with more elaborate arrangements, can deal with relatively weak signals; their performance in this respect is called *sensitivity*. (3) Demodulation, i.e. the separation of the relatively low-frequency speech, music or vision component from the radio-frequency carrier wave. (4) Conversion of the demodulated signal, after suitable amplification, into sound or light.

Receivers are generally classified under two main headings, (a) the type known as T.R.F. (tuned radio frequency), in which all R.F. amplification is carried out at signal frequency and (b) *the superheterodyne*, which differs from a T.R.F. receiver in that after the desired signal is initially selected, its original frequency is changed to another frequency before amplification and demodulation (see SUPERHETERODYNE RECEIVER).

All receivers, apart from simple crystal sets, require power to operate them and the source of this power provides other classifications. In

battery-operated receivers, lead-acid accumulators provide the low-tension supply to the valve filaments and dry batteries are used for the anode circuits; *all-dry* receivers use dry batteries for all purposes; *mains-operated* receivers derive all their power from supply mains. This last type is further divided according to whether the set operates on A.C. or D.C. *Universal* receivers are mains-operated and function on either A.C. or D.C. mains. Finally, there are special types which include those which will work on A.C., D.C., or batteries, and sets in which a lead-acid accumulator provides L.T. and, in conjunction with a vibrator (q.v.), the H.T.

Explanations of other features and parts of receivers are given under: AERIAL; ALL-WAVE RECEIVER; AMPLIFICATION; BAND-PASS TUNING; BATTERY ELIMINATOR; DEMODULATION; LOUDSPEAKER; POWER PACK; TELEVISION; TONE CONTROL; TUNING and VALVE AMPLIFIER.

RADIO SERVICING. That branch of radio engineering which deals with the upkeep and repair of radio equipment. Maintenance of high-power transmitters and similar apparatus is a very highly specialized undertaking and is not generally understood to be covered by this term.

The diagnosis of faults in a radio receiver or component cannot, except in a few instances, be carried out without a certain minimum of test equipment. Some troubles, such as severed connexions or mechanical failure, can often be observed by mere inspection; but faults often occur in inaccessible places and can then be detected only by electrical test. Suitable equipment includes a "universal" test set, which comprises a combined voltmeter, ammeter and ohmmeter; adequate tools; spare parts; and, if necessary, specialized apparatus.

The general principle in fault-finding in radio receivers is to begin at the end; that is, the power supplies and loudspeaker should be checked first, followed by stage-by-stage tests right through the set to the aerial or until the fault is found. This method prevents the possibility of one fault being masked by another and often saves much unnecessary labour.

RADIO VALVE. An electronic device depending for its operation upon electrons emitted from a heated cathode. Modern thermionic valves are almost certainly the result of

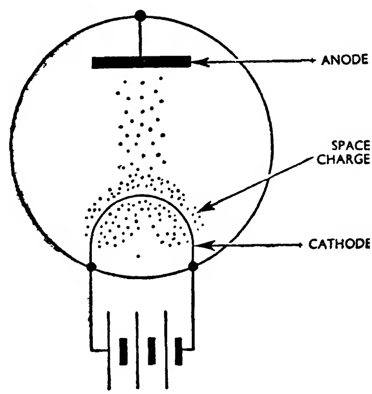


Fig. 1. Showing working principle of a simple two-electrode valve consisting of a heated filament and an anode.

development of the Edison effect. In about 1884, Edison discovered that, if a metal plate were sealed into a carbon lamp between the legs of, or near, the filament, a galvanometer connected between that plate and the positive end of the filament showed that a current apparently passed through the vacuum between plate and filament.

In 1904 Fleming, who had repeated Edison's experiments, developed a simple two-electrode valve or diode, consisting of a heated filament and an anode enclosed in an evacuated glass vessel. The working principle is briefly as follows. Surrounding the heated filament or cathode (Fig. 1) is a cloud of liberated electrons, known as a space charge, which, from its nature, is negative. Under the influence of a positive anode, some of the electrons leave the space charge and travel to the anode, their place being

taken by electrons newly liberated from the cathode. This passage of electrons from cathode to anode constitutes an electric current flowing between those two points.

Thus, so long as the anode does not attempt to attract electrons as fast as they are emitted, the space charge is maintained in a state of equilibrium. If, however, the anode is sufficiently positive to collect the electrons as fast as they are liberated, saturation is said to occur and the electron-flow from cathode to anode is limited, further increases in anode potential having no effect on anode current (Fig. 2). If now the anode is made negative relative to the cathode, the space charge is repelled and no anode current can flow. A diode is thus essentially a unilateral conductor and can be used as a demodulator for radio-frequency signals or for rectification in general.

About three years later, in 1907, Lee de Forest introduced between cathode and anode a further electrode in the form of a mesh or *grid* with a view to controlling the anode-cathode current electrostatically by applying a voltage to the grid. The introduction of this third electrode to constitute a triode made such a valve exceedingly useful and opened a wide field of applications. One of its first applications was its use in land-line telephone circuits as a repeater (amplifier), resulting in better and easier trunk communications, and it was soon discovered that a triode, with proper circuit arrangements, was capable of generating continuous high-frequency oscillations, which are the basis of modern radio communication.

Certain difficulties were encountered when triodes were used as radio-frequency amplifiers, and circuits tended to be unstable in operation. However, a discovery, attributed to Hull, produced the tetrode or screened-grid valve and the difficulties were largely overcome. In a tetrode, a second or screening grid is placed between the control grid and anode, effectively shielding

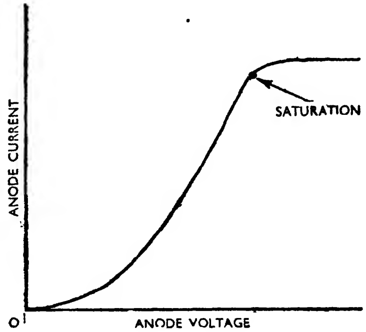


Fig. 2. Voltage/current characteristics of the anode of a diode.

the former from the latter; in other words, it is so arranged that variations of anode voltage have little effect on the control grid or cathode. Effects associated with secondary emission limited the use of a tetrode to dealing with relatively small swings of anode voltage. In 1929, yet another grid, called the suppressor (from its apparent effect on secondary emission) was placed between the anode and the screening grid and connected to the cathode. This five-electrode assembly, which is called a *pentode*, overcomes the limitations of a tetrode.

There are valves with even more grids, such as hexodes, heptodes and octodes, and they differ essentially from simpler valves in that they have more than one control grid. It is quite usual these days to include several valve assemblies in a common glass envelope and thus, for example, double-diode-triode simply means that there are three valves, namely two diodes and one triode, in one enclosure, usually sharing the one cathode.

In the earliest types of valve, the cathode was simply a thin filament of tungsten operated at a very high temperature—equivalent to about white heat. Emission depended very critically on filament temperature and such an arrangement was not very economical owing to the relatively large power required to heat the filament, whose life was rather short

at the necessarily high working temperatures.

Some time later an advance was made with the introduction of the thoriated filament, which was essentially tungsten as before, but with a mixture of thorium. After suitable activation, the tungsten wire acquired a very thin, probably molecular, layer of thorium on its outside. Such a filament gave good emission at much lower temperatures and was, therefore, more economical and longer lived.

Cathodes of modern receiving and small transmitting valves are oxide coated. A mixture, generally of barium and strontium oxides, is sprayed on to a tungsten wire. Such a coating gives a copious electron emission at dull-red heat, and a valve employing such a cathode was originally called a dull-emitter. Cathodes of this type, however, are not well suited to heavy duty and nearly all high-power valves still have pure tungsten or thoriated filaments.

It is not possible here to study the characteristics of all types of valve and, accordingly, the following applies particularly to triodes. Ignoring conditions brought about by variations of cathode temperature, there are three "constants". First, there is anode A.C. resistance, which, the grid voltage being kept constant, may be defined as the ratio

$$\frac{\text{a small change of anode voltage}}{\text{corresponding small change of anode current}}$$

and is expressed in ohms; the symbol used is r_a. Secondly, there is mutual conductance, for which a definition is

$$\frac{\text{a small change of anode current,}}{\text{a small change of grid voltage}}$$

the anode voltage being kept constant. The symbol is g_m and it is expressed in amperes per volt. Lastly, there remains amplification factor, sometimes called magnification factor, which is defined as the ratio

$$\frac{\text{a small change of anode voltage}}{\text{a small change of grid voltage}}$$

to give the same change in anode current; its symbol is μ; it is simply a number. These three constants are related in such a way that $\mu = g_m \times r_a$.

Since a small voltage acting on the grid of a valve is equivalent to a large voltage acting on its anode, it follows that amplification is possible; that is, the production of a large voltage by a small one or the generation of a relatively large amount of power from a small amount. It must not be imagined that the valve itself generates energy; it merely controls power from a suitable source and changes it to the desired form. By connecting the anode circuit of a triode, with due regard to phase, back to its grid circuit, the amplifier provides its own input, and continuous oscillations may be generated. Other valve applications range from simple devices such as rectifiers to complete systems such as radio transmitters and receivers, and radiolocation installations.

RADIO-WAVE PROPAGATION. Radio waves are of the same nature as light and heat waves, and consist of electro-magnetic and electric stresses travelling through the ether at a velocity of approximately 300,000,000 metres per second.

Light, as is well known, travels in straight lines and can pass through only a few substances. This is because light waves are very short, i.e. correspond to oscillations of very great rapidity, and the electrons in the substance on which the waves fall are able to vibrate in sympathy and so absorb the energy of the wave. As the wavelength becomes longer, the electrons are less able to respond and thus the wave penetrates further.

Clerk Maxwell and others calculated, many years before the behaviour of radio waves became known, that, if waves of a lower frequency than light or heat could be produced, they would penetrate most objects such as buildings and would, therefore, travel great distances without much attenuation.

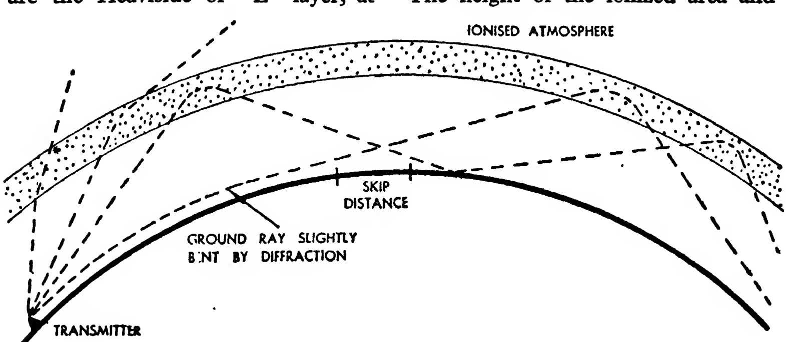
For this reason, Marconi and others made transmitters working on very long wavelengths up to as much as 30,000 metres, that is 10 kc/s. These

long wavelengths, in conjunction with high powers, are used even today for certain commercial transmissions and give reliable results over great distances. When broadcasting became a public service, the many new transmitters had to take shorter wavelengths between 200 and 3000 metres, whilst amateurs and experimenters had to work on even shorter wavelengths, the use and application of which commercial and public authorities did not, at that time, fully appreciate. It was not long, however, before these apparently useless short waves were found to provide satisfactory signalling over thousands of miles using only a very low power.

It was discovered that, owing to the action of the sun's rays on the upper layers of the atmosphere, the earth is surrounded by a belt of electrified, or *ionized*, gas. Owing to reduced pressure in these regions, electrons have comparative freedom and the impact of certain of the sun's rays is sufficient to separate many from their atoms. This ionized band was first known as the Heaviside layer after its discoverer, but subsequent investigation has shown that there are actually several layers which are known jointly as the *ionosphere* (q.v.). The most important of these belts are the Heaviside or "E" layer, at about 60 miles above the earth's surface, and the Appleton or "F" layer, at approximately three times that height.

Radio waves travel faster when they enter an ionized region and, consequently, when a wave enters such a layer at an angle, the top part, which enters first, speeds-up and the whole wave turns. In certain circumstances, depending upon the degree of ionization, the wave may be completely turned and reflected back to earth. On striking the earth, which is a fairly good conductor, reflection again occurs and so the wave zig-zags round the earth until all its energy has been absorbed.

One interesting result of this is that there are areas where, even though close to the transmitter, reception cannot be obtained, the most notable being the region where neither direct nor reflected waves can be received. The lengths of these "silent" areas are known as skip distances, as indicated in the accompanying sketch. It will be appreciated that, although in the diagram the waves are represented by a single line, they should in fact be shown by innumerable lines fanning out from the aerial; this means that after the first reflection the transmission is diffused over a large area. The height of the ionized area and



TRANSMISSION OF RADIO WAVES.

In this diagram explaining radio-wave propagation, is shown the refraction (bending) and reflection of waves by the ionosphere. The ground ray tends to "drag," following, to some degree, the curvature of the earth. The area marked *skip distance* is out of range of the ground ray. It is too close to the transmitter to receive a reflected ray, because a wave, leaving the transmitter at an angle suitable if the ionosphere were a perfect reflector, is merely refracted and lost.

the degree of ionization vary with the time of the day and the season of the year, and are also affected by the cyclic variation in sun-spot activity. The higher radio frequencies are most susceptible to these changes in condition. This partly explains why distant reception, particularly on short waves, is variable and why transmitter frequency is altered to secure maximum propagation according to the time and the route. In spite of these difficulties, short waves are usually employed for long-distance communications because, in general, they are less inclined to scatter than long waves, they suffer less attenuation, and it is relatively easy to provide directional aerial arrays. This last statement will be more readily understood when it is realized that an aerial should have a direct relation to the wavelength transmitted, and it is evidently much simpler to accomplish this at, say, 10 metres than at 1000 metres.

Variations in reflection from the ionized belts are largely responsible for fading or random variation of signal strength, one form occurring when both direct and reflected waves arrive at the receiving aerial. The height of the ionized layer may be altering, so changing the distance travelled by the reflected wave. Sometimes, therefore, the latter arrives in phase with the direct wave and sometimes out of phase, so that the resultant signal increases and decreases.

The second form of fading occurs when only the reflected wave is being received, and is due to the wave becoming twisted during reflection. A normal radio wave is polarized and produces maximum signals in an aerial set at a given angle. The uneven reflecting layer and varying densities within it may, however, cause the waves to twist or spin and, as a result, the plane of polarization will rotate, causing the induced signal at the receiving aerial to change in strength. The degree of this rotation may depend very critically on frequency; thus certain side-bands of telephony (music) transmission may be treated quite differently from other side-bands in the same transmission. This is one reason for the peculiar tonal distortion which is sometimes heard in short-wave reception and is known as *selective* fading.

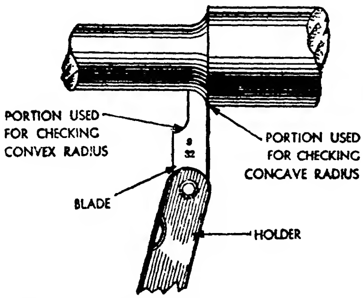
Reflection is not limited to the short waves; its effects are noticeable to nearly 1000 metres and attenuation at, or in, the ionized layers becomes more pronounced at lower frequencies. In general, attenuation is maximum in daylight and thus certain stations, particularly those in the medium waveband, produce signals which are received with increased strength after nightfall.

The behaviour of very short waves —those of about 10 metres and under—corresponds more closely with that of light. These waves have little penetrating power; hills and even buildings can cast "shadows"; they also tend to pass through the ionized layers without ever being reflected and seldom return to earth. They are valuable for certain purposes, permit highly localized broadcasting, and provide a system of relaying signals from point to point almost as if one were using a focused beam of light.

RADIUM (Ra). Atomic no. 88; atomic wt. 226. An element resembling barium in its chemical properties. Its most remarkable property is that it is continually emitting α particles and γ rays, producing the radio-active gas, radon (q.v.) or niton, while the residue undergoes a number of changes until finally the metal lead is left. The change is a slow one, radium losing half its weight in 1580 years.

RADIUS GAUGE. A device, also known as a *fillet* gauge, for measuring the radius of curvature, usually at a change of section in turned metal components. The avoidance of sharp changes of section wherever possible is a cardinal principle in engineering design.

It has been proved beyond all doubt that the existence of right-angled "steps", in leading from one diameter or cross-sectional area to



Radius gauges are usually designed so that both convex and concave curves may be checked with the same blade.

another, is a fruitful source of cracks which may develop during service, especially in moving parts working under stress and subject to fatigue. It is therefore most important to avoid, whenever possible, sharp corners (in machined work, as well as in castings and forgings), and to provide a radius or rounded transition —sometimes convex, sometimes concave—at each change of section.

In machining such a "radius", the operator can either work to an estimated profile by hand operation or use a tool ground as nearly as possible to the correct shape, or use as a check the series of accurately shaped radii comprised in the series of metal strips forming what is known as a radius gauge, shown in the illustration. In either case he must check the finished article, and this can be done satisfactorily only by using a radius, or fillet, gauge.

Such gauges usually consist of a number of metal strips or blades in a holder which generally resembles the handle of a double-bladed pocket knife. For simplicity, these blades are often shaped so as to provide a convex radius at one portion of their profile and a concave section of equal radius at another portion of the profile of the same blade.

RADIUS ROD (Aero. Engineering), see UNDERCARRIAGE.

RADON (Rn). Atomic no. 86; atomic wt. 222. An inert gas, formerly called niton, resembling neon and helium in that it forms no chemical compounds. It is the first product of the spontaneous decomposition of radium and has been known as "radium emanation" or "niton." It undergoes a radioactive decomposition itself, forming in succession radium A, radium B, RaC, RaC^1, RaD, RaF (polonium) and finally an isotope of lead with an atomic weight of 206.

RAIN-WATER HEAD. A flared-out termination to rain-water pipes intended to assist in the quick discharge of rain-water from roof gutters. Rain-water heads also offer facilities for reaching stoppages in down pipes.

RAM. The increase in the pressure and density of the air entering the intake to the carburettor of an engine which faces forward, due to the effect of the speed of the aeroplane. These increases are transmitted through the induction manifold to the cylinders, resulting in an increase in power.

Alternatively, the manifold pressure or boost, which is obtained without the effect of the forward-facing intake, can be obtained at a greater altitude with about the same power output due to ram effect. This increase in altitude ranges from about 1000 ft. at 200 m.p.h. to 4000 ft. at 400 m.p.h.

RAMAN EFFECT. When light of a definite wavelength is scattered by the molecules of a solid, liquid or gas, light of different wavelengths may be produced by the vibration or rotation of the molecules. The study of this phenomenon has proved of value in determining the structure of many molecules; the method was originally investigated by Raman in 1928.

RANGE. The range of an aeroplane is the distance it can fly with a given quantity of fuel on board without refuelling. The range will vary with a fixed quantity of fuel according to the speed at which the aeroplane is flown.

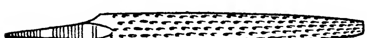
As the speed is reduced from the maximum, under which conditions the fuel consumption is very heavy, the range will increase rapidly, and there will be a speed which is the best compromise between speed and range, after which any further

reduction in speed will result in a loss of range.

RARE-EARTH ELEMENTS. Members of a group of trivalent metals with atomic numbers 57 to 71, e.g. lanthanum, cerium etc. The two named are better known than the others and have some industrial use. Most of the others are very rare, and in many cases the element itself has not been isolated.

RARE GASES. The name given to the gases helium, neon, argon, krypton, xenon and radon; the first five of these occur in small amounts in air. The rare gases are chemically inert and monatomic.

RASP. A tool, shaped like a file (q.v.), but having a large number of small projecting teeth instead of furrows. For shaping small circular work, it is a very useful and fast-working tool. Rasps may be obtained in varying degrees of coarseness, and may be round or flat on the face.



Rasp used in woodwork for shaping round surfaces. Note projecting teeth.

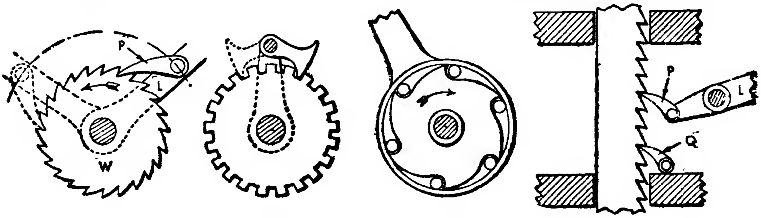
RASTER. A pattern of lines traced by the light spot on the screen of a cathode-ray tube, corresponding to scanning (q.v.).

RATCHET DRIVE. A method of imparting movement to a toothed mechanical component, the motion usually being derived from some reciprocating part. Ratchet gearing or drive is used in a wide variety of forms in various mechanical applications, perhaps the most important being the "feed" motions of machine tools. The basic type is shown at (a) in the illustration, where the pawl P is hinged to an oscillating lever L which enables an intermittent rotational movement to be imparted to the wheel W. This device can also be used to prevent rotation of the wheel except in a predetermined direction, i.e. away from that in which the pawl is pointing.

At (b) is shown a *reversible* ratchet gear, widely used for machine tools of various kinds, especially slotters and shapers. The wheel teeth and pawl are of such profiles that by merely reversing the position of the latter, either side can take the drive.

Friction-operated gears, of which an example is shown at (c), are used in various applications where any unpredictable chance resistance to a positive drive might cause trouble. In this type the outer ring provides the drive through the oscillating lever, and the rollers or balls are arranged to wedge between the wheel and the ring as they tend to travel up the sloping planes which are the equivalent of ratchet teeth.

Another type of ratchet drive (d), shows a means of imparting a straight-line, instead of a circular, movement to the driven member. This motion is often used in lifting jacks. The pawl P is hinged to the jack lever L and effects the actual lifting, pawl Q holding the load and preventing it from falling whilst lever L and pawl P are being returned to their initial position in readiness for another lift.



(a) (b) (c) (d)

Ratchet drive, four types of which are shown, has a variety of applications in engineering although the basic principles are virtually the same in each case.

RATED ALTITUDE AND POWER. The operational limits of engines for various flight conditions, such as climb, weak-mixture cruising etc., are laid down in terms of maximum permissible revolutions per minute and boost. The rated altitude is that at which the maximum permissible boost for a given operating condition or rating is obtained with the throttle fully open, and the maximum permissible R.P.M. The rated power is the power under this condition.

RATE-OF-CLIMB INDICATOR. An instrument which uses the change of atmospheric pressure with altitude to measure the rate at which an aeroplane is climbing. It consists of a small thermally insulated chamber, which is connected to the atmosphere by a very small hole, and also to one side of a sensitive diaphragm, the other side of which is exposed to the atmosphere.

When the aeroplane is flying level, because of the small hole a state of equilibrium is reached, and the pressure in the chamber is equal to the atmospheric pressure. The diaphragm is thus undeflected, and zero rate of climb is recorded by the pointer which is coupled to the diaphragm. Consider now what happens when the aeroplane is climbing. The pressure in the small chamber will rise above that of the atmosphere, because the air cannot escape fast enough through the small hole. A differential pressure is thus applied to the diaphragm, which is deflected, and the rate of climb is indicated.

As the ratio of the air pressure in the small chamber to atmospheric pressure is a function of the rate at which the aeroplane is climbing, the instrument can be calibrated to indicate the rate of the climb of the aeroplane in any desired units. When the aeroplane is descending the process is repeated in reverse and the rate of descent is indicated.

RATING (Elec. Engineering). The output of an electrical machine which may not be exceeded without danger of damage. Generally it is the temperature rise which determines the rating. The rating depends upon the conditions of use and may be qualified, as in the case of maximum continuous rating, one hour rating, or intermittent rating.

RAW SIENNA, see SIENNA.

RAW UMBER, see UMBER.

REACTANCE. Symbol: X. The part of an electrical impedance (q.v.) which is due to inductance and/or capacitance. The practical unit is the ohm. See ALTERNATING CURRENT.

REACTION. Also known as retroaction or regeneration. The introduction to the grid circuit of a radio valve of a part of the signal energy in its anode circuit, such that the feedback is in phase with the original signal. The term is generally applied either to certain types of valve oscillators or to leaky grid demodulation stages.

Reaction, however produced, is equivalent to altering the effective resistance and reactance of the grid circuit, and energy fed back in the proper phase will "neutralize" part or all of the resistance of an input circuit.

In the latter case, the whole circuit will oscillate, and in the former, an effect will be produced which is equivalent to added amplification.

REACTIVE COMPONENT. The component of an alternating electric current or voltage whose vector is at right-angles to the vector of voltage or current. Synonyms: idle component, quadrature component, wattless component. See ALTERNATING CURRENT.

REACTIVE VOLT-AMPERES. Symbol: VAR. An electrical term signifying the product of the reactive component of an alternating voltage and a current, or of the reactive component of the current and a voltage. A measurement of this quantity and the power enables the power factor (q.v.) to be found. See ALTERNATING CURRENT.

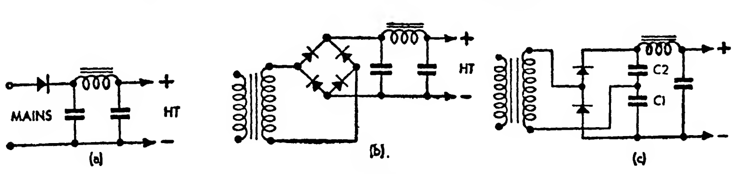
REACTOR. An electrical circuit component designed to possess reactance (q.v.). The term is usually restricted to inductors. See INDUCTOR.

REAMER. A tool for slightly expanding, and imparting a finished surface to, holes previously drilled. It is made either tapered or parallel, or sometimes has a parallel portion combined with a tapered end. Holes requiring accurate internal finish are drilled nearly to size, then reamered to finished dimensions on the drilling machine, the reamer being provided with the standard Morse taper for insertion in the machine spindle.

The cutting action of the reamer is derived from the flutings (shown in the accompanying illustration),

Holes made by a drill or boring bar are finished off accurately by means of a machine reamer, for which purpose a special holder is required.

machined either spirally or longitudinally on its surface. The entire edge of each fluting thus forms a cutting edge. Expanding reamers have been devised for use where very accurate machining is needed. The cutting edges are then arranged on separate portions of metal, grouped around a conical centre piece which can be adjusted by a locking screw; the end of the cone is graduated, and a movement of the screw through one division will



TYPICAL RECTIFICATION CIRCUITS

Fig. 1. Three methods of rectification: (a) simple half-wave system using a metal rectifier; (b) full-wave bridge arrangement frequently used with metal rectifiers but seldom with valves; and (c) the voltage-doubler circuit which is often employed when it is not desired to provide a transformer for the full voltage.

result in an increase in diameter of, say, $\frac{1}{1000}$ in., thus permitting very fine adjustment to be made.

Floating heads are used for reamers when machining large holes, to provide freedom for the cutting portion to follow the hole being expanded. The machining allowance, when using reamers, depends upon the material to be machined and the diameter of the hole; from 0·01 in. is the most widely used range. Special precautions are necessary when they are used with aluminium or magnesium, because the metal is inclined to close in upon the reamer during the cutting operation; a size of reamer slightly in excess (0·0055 to 0·0015 in.) of the normal is, therefore, necessary.

REBATED JOINTS, see JOINTS.

RECALESCENCE POINT, see HARDNESS.

RECORDING PYROMETER. A pyrometer (q.v.) used in sheet-metal work throughout the continuous-rolling process to measure the metal temperature rapidly. In rolling-mill work, such instruments usually comprise a thermotube, a recorder and an indicating dial.

The hot metal passes under the thermotube (e.g. one is generally placed above the roller conveyor before the first stand of the hot-finishing), and by means of a potentiometer measuring circuit the temperature is determined. The reading is transmitted electrically to the recorder and indicating dial.

It is customary for recorders to be situated on the master control boards, the indicating dials being in full view of the operators in the control pulpits.

RECTIFICATION. The process of converting an alternating voltage into a uni-directional one. The term may

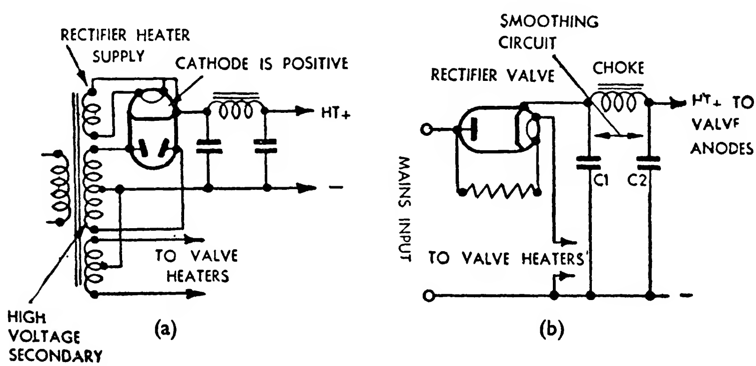
be applied either to obtaining direct current from alternating current supply mains or to demodulation of radio signals. In this latter connexion, see DEMODULATION.

A.C. mains-operated receivers require a direct-current H.T. source for the anode circuits of the valves, and it is necessary to introduce rectification to provide such a supply. Various arrangements are possible, and some typical circuit diagrams are shown in Fig. 1. The output of the rectifier itself would contain a large ripple component which must be filtered out, and the illustrations include the conventional smoothing requirements. In almost all cases, a transformer is interposed between the A.C. supply and the rectifier. It fulfils the dual purpose of isolating the radio circuits from the mains and of providing any desired voltage; various heater supply-windings are also generally included. Fig. 2 (a) shows a full-wave rectification system with centre-tapped secondary winding and provision for heating other valves.

Most radio receivers are provided with thermionic vacuum valve rectifiers, since they are relatively cheap; metal rectifiers tend to be unduly expensive for H.T. purposes but they are reliable and robust, and last almost indefinitely. In powerful radio receivers and amplifiers, mercury-vapour rectifying valves are sometimes used because of their low effective resistance when conducting. Better voltage regulation is obtained, but special precautions have to be taken.

In particular, it is necessary to allow their cathodes to become thoroughly heated before applying anode voltage. For information on suitable filter arrangements, see SMOOTHING.

RECTIFIER. A piece of electrical equipment for the conversion of alternating current to uni-directional current. See MERCURY-ARC RECTIFIER and METAL RECTIFIER.



THERMIONIC-VALVE RECTIFIER

Fig. 2. Most widely used arrangement (a) incorporating a thermionic-valve rectifier comprising two diodes with a common cathode and enclosed in the same envelope, and (b) in cases where the provision of a transformer is not convenient, or is for other reasons undesirable, the half-wave system illustrated is favourable.

RED BRASS. An alloy containing 85 per cent copper, 5 per cent tin, 5 per cent lead and 5 per cent zinc. It is used as a substitute for gunmetal in a variety of work. British Standard Specification No. 898, 1940, for Leaded Gunmetal Castings, covers this alloy. The range of composition allowed is zinc 4 to 6 per cent, tin 4 to 6 per cent, nickel 1 per cent max. and other elements, except oxygen, 0·50 per cent.

The mechanical test requirements are ultimate stress 12 tons per sq. in. with an elongation of 8 per cent for

bars cast on the casting. For separately cast bars 12 per cent elongation is required. The alloy is decidedly more resistant to acid attack than ordinary gunmetal, and is often used for pump parts dealing with acid mine waters.

REDIFFUSION. A system by which broadcast radio programmes are distributed to subscribers by wire, special permission having been granted by the Postmaster-General. The operating company may relay, by such means, only ordinary broadcast items and are not themselves permitted to originate programmes.

Broadcast material is received either by elaborate installations situated away from areas of interference or by direct wire from the studio, thus ensuring good reception, and the output of suitable amplifiers is fed into wires laid on to the home. Equipment in the home consists of only a loudspeaker fitted with a volume control and, often, a switch which enables the listener to select an alternative programme.

RED LEAD. Heavy bright-red powder formed by the combination of the metal lead and oxygen. For painting purposes this powder must contain not less than 72 per cent Pb_3O_4. This type or grade, when mixed with sufficient refined linseed oil to form a usable paint, will retain that quality for 24 hours.

A non-setting type of red lead, containing 99·5 per cent of lead oxides of which not less than 93·15 per cent is Pb_3O_4, can be ground into a stiff paste with 8 to 10 per cent of refined linseed oil and further thinned to a working consistency with the same oil; it will retain for fourteen days a proper consistency for painting.

Red lead is the best primer to use upon ironwork, and, in combination with white lead, should form the pigmental portion of all priming paint used upon timber and plaster.

RED MAHOGANY, see EUCALYPTUS.

RED PRECIPITATE, see MERCURY.

REDS. The main reds used by painters are the pigments which derive their colour from iron compounds; they are generally termed oxides (q.v.), and have a considerable range in both hue and tone. They may also be called *light* red, *Venetian* red and *Indian* red. The pale colours have a yellowish hue, but the deep-toned colours develop a bluish tint. In admixture with white pigments they all develop a bluish hue; all form very opaque oil paints, the darker colours being extensively used for general utility and ironwork painting.

Burnt sienna, a dull-red transparent pigment used mainly for the production of glazes, tends to have a yellow hue. Lead chromate (chrome red), sold under various proprietary names, provides a rich, dull red when used alone; but in combination with white pigments it gives a satisfactory range of tints and in combination with linseed oil forms a good protective coating for ironwork. Red lead is a bright red suitable only as a pigment for priming paints. It is the best pigment to use for the protection of ironwork. Vermilion is a bright scarlet powder, but its cost restricts general use.

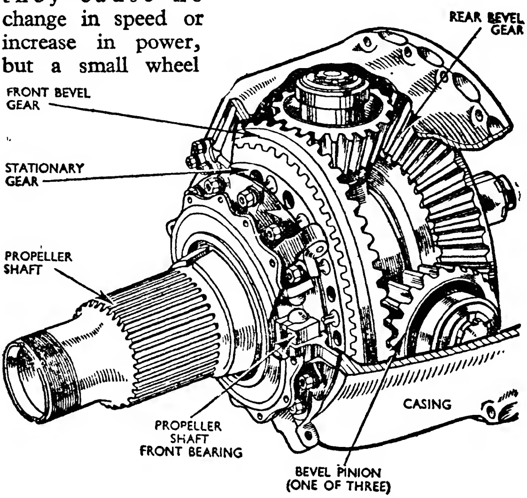
Many pigments which resemble vermilion in colour are produced by fixing a dye upon lead chromate, red lead, white lead or other white bases; they are all sold under proprietary names.

Lakes (q.v.) provide a considerable range of red-hued pigments, and are formed by fixing a dye upon a transparent base.

REDUCTION. In chemistry, the term has a special significance and means the removal of the whole or part of the oxygen from a compound, or the whole or part of some other element from a metallic ore, so as to yield the metal. For some purposes, the addition of hydrogen to a compound is almost equivalent to the loss of oxygen, and so this change is sometimes known as reduction.

The word is also used to denote the change of a metal in a compound from a high valency to a lower valency, so that the change of a ferric salt to a ferrous salt, or of a cupric salt to a cuprous salt, is known as reduction.

REDUCTION GEAR. A system of decreasing, by the use of gear-wheels of different sizes, the speed of a driven shaft relative to that of the driving member. If two gear-wheels of the same size are meshed together they cause no change in speed or increase in power, but a small wheel meshed with a larger one will rotate the latter at a reduced speed, dependent upon the ratio of teeth on each wheel.



Bevel-epicyclic reduction gear of the type which is fitted to the "Bristol" Hercules radial engine.

On road vehicles driven by an internal-combustion engine, since the power output of such engines is dependent on a fairly high speed of rotation, some arrangement must be incorporated whereby the speed of the propeller shaft in relation to that of the road wheels can be reduced. Similarly, in aircraft, reduction gearing, such as shown in the accompanying diagram, is employed to decrease the speed of rotation of the propeller in relation to the crankshaft.

While high operating speeds of the aero engine are needed for maximum power, high propeller speeds usually mean loss of propulsive power and efficiency owing to slip, so that reduction gearing between crankshaft and airscrew shaft is necessary. For in-line engines, some form of spur-type gear is commonly employed, but radial engines have an epicyclic arrangement so that the airscrew shaft is kept in the same centre-line as the crankshaft.

REDWOOD. The most popular wood used in building. It is found in N. Europe and is also known by many other names, such as Scotch fir, Northern pine, red and yellow deal etc. It is pleasant and easy to work, resinous, strong and durable, and is extensively used for constructional work, doors, windows etc.

REFINED LINSEED OIL, see LINSEED OIL.

REFLEX CIRCUIT. A radio circuit in which a single valve is made to perform two duties, generally to amplify simultaneously at two widely different frequencies. For example, the intermediate frequency amplifier in a superheterodyne receiver may also be used as the first low-frequency voltage amplifying stage. Such a system was quite popular when valves were expensive and scarce, but it is not now much used.

REFRACTION. When light falls obliquely on to a flat surface of a transparent liquid or solid, the ray of light is refracted, or bent, when it penetrates the surface, as shown in the accompanying diagram. It is also refracted when it leaves such a

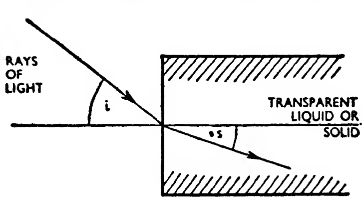


Diagram showing how a ray of light is bent in penetrating the flat surface of a transparent liquid or solid.

surface and enters another transparent liquid or solid or the air.

Every transparent body has its own refractive index, denoted by n or μ, which is defined as $\frac{\sin i}{\sin s}$ where i is the angle of incidence and s is the angle of refraction. Water has a refractive index of about 1·33, glycerine about 1·47, benzene about 1·5, aniline about 1·58, flint glass about 1·6, diamond about 2·4.

REFRACTORY MATERIALS. Materials which will stand a high temperature, for instance about 1500 deg. C., for a prolonged period. They are chiefly used for the lining of furnaces, and for this purpose they must stand not only the high temperature but also dust, slag and hot gases. They include fireclay, silica, ganister, coke, lime, magnesia, alumina, dolomite and zirconia.

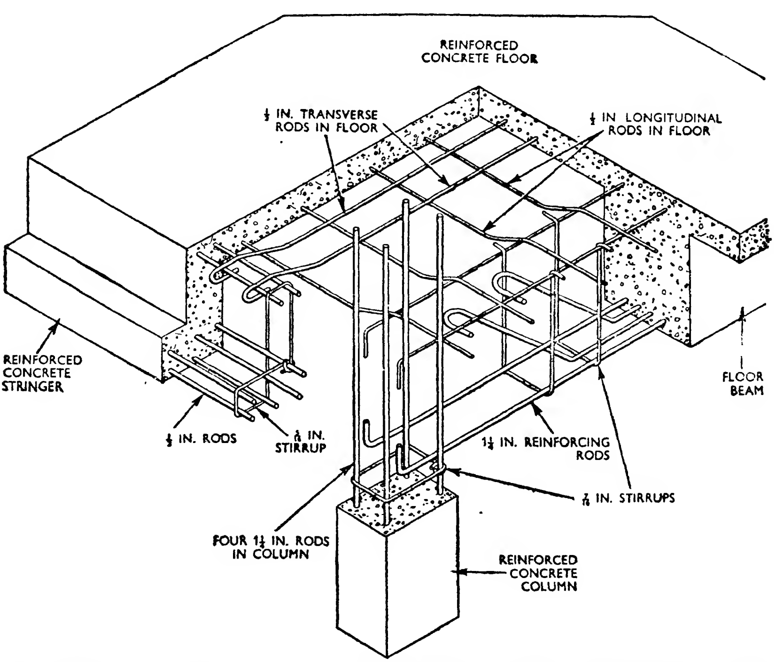
REGENERATION. Another term for reaction (q.v.).

REGULATION. The change in the output voltage of an electrical machine caused by putting on or throwing off a specified load, other factors, such as speed or input voltage, remaining constant. It is usually expressed as a percentage of normal voltage.

REINARTZ CIRCUIT. A valve receiver circuit employing capacitance-controlled reaction.

REINFORCED BRICKWORK. To assist in strengthening brickwork steel rods or hoop iron may be inserted in the joints between bricks. Hoop iron has been frequently used for this purpose, especially at quoin angles and wall junctions, but a recent development is the introduction of steel rods placed vertically and buried in the mass of brickwork. To accommodate the vertical reinforcement, a special type of bonding may be adopted, but Flemish bond can be used for this purpose.

REINFORCED CONCRETE. A combination of steel and concrete,



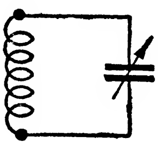
Combinations of steel and concrete are used in building construction to add strength to the structure. Arrangement of reinforced-concrete floor is shown.

each material being applied to its best advantage. The steel is used for the purpose of taking the tensional stresses, whilst the tensile strength of the concrete is neglected. The reinforcement is embedded in the concrete, as shown in the illustration overleaf, with due regard to the distribution of the stresses to which the concrete offers little or no resistance.

Buildings of reinforced concrete may be constructed so that the floors and roofs rest upon, and are linked with, exterior and interior columns, the walls and partitions merely filling the panels between the structural members. The structural frame consists of vertical columns, or pillars, and horizontal beams, which are linked together by the steel reinforcement, thus making the structure monolithic in character.

REJECTOR CIRCUIT. A tuned radio circuit consisting essentially of a coil and condenser in *parallel* as shown

Coil and condenser in parallel constitute a rejector circuit.



in the accompanying diagram. At resonance, the reactive components of the impedance cancel out and, in the absence of resistance or other losses, the impedance is infinite. The circuit is so called because it "rejects" current at resonance. See TUNING.

RELATIVE DENSITY. The ratio of the density of air at any altitude to that at sea level under standard conditions, the latter being 0·00238 slugs per cubic foot. See SLUG.

RELATIVE HUMIDITY. An important factor in printing for the reason that paper is a hygroscopic material, and takes in moisture or gives it out to the air until the two are in equilibrium. Increased moisture swells the individual fibres of the paper, while increased dryness contracts the fibres.

These fibres are roughly tubular in shape, and they swell across their width several times more than in the long direction; it follows, therefore, that the paper sheet changes across the grain more than in the fibre and machine direction.

It is of the utmost importance for perfect results in register work that the relative humidity shall be constant, also that the machine direction of the paper shall be *across* the cylinder, because of the possibility of slight peripheral control.

When paper and atmospheric humidity are not balanced the paper edges contract or expand, and curling and creasing take place during printing.

Other things which are affected by changing humidity are printing rollers; printability of paper; set-off; smearing and drying of printing ink; static electricity in paper; folding and creasing of paper stock, wood block-mounts and furniture; exposure times in printing-down (photo-litho); and rate of etching of gravure plates and cylinders. See PAPER HYGROMETER.

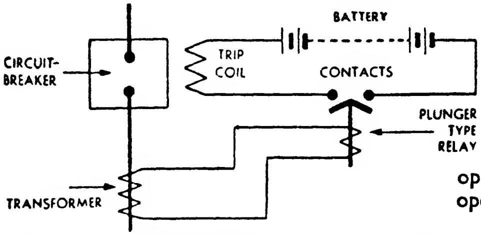
RELAXATION OSCILLATOR. In radio, an oscillator in which the oscillatory frequency is determined, not by a resonant circuit, but by a change of current or voltage through the charging or discharging of a condenser when a certain critical value is reached.

An oscillator of this kind is inherently unstable but is readily synchronized with an external controlling voltage. Its output is very rich in harmonics and thus it can be used as a frequency multiplier.

Since it is possible to synchronise the device by a frequency corresponding to one of its harmonics, it will also serve as a frequency divider. One of the most useful and versatile forms of relaxation oscillator is the multivibrator (q.v.).

RELAY. An electrical device which causes a change in circuit conditions, such as a change of voltage, to produce a change in the same circuit or another circuit.

In this way, for example, an excessive current in a feeder may operate a relay which causes the feeder circuit to be interrupted by



When an excessive current flows through the feeder, the current in the transformer secondary is sufficient to operate the relay. When the contacts are bridged the battery operates the trip coil which opens the main circuit breaker.

means of a circuit-breaker as shown in the diagram. See PROTECTIVE GEAR.

RELIEVING ARCH. An arch, intended to discharge the weight of the wall above openings to the abutments, and consisting of two or more consecutive rings of stone or roughly-cut bricks built on a core, shaped to a required curve. Such arches are seldom used in modern construction, some form of reinforced concrete lintel being preferred.

RELUCTANCE. Symbol: S. A property of a magnetic circuit which is analogous to resistance in an electrical circuit. It is proportional to length and inversely proportional to area and permeability (q.v.). The magnetic Ohm's Law is that flux is equal to m.m.f. divided by reluctance.

RELUCTIVITY. A magnetic quality analogous to resistivity. It is the reciprocal of permeability (q.v.).

REMAGNETIZING. The re-energizing of a permanent magnet, carried out by the aid of a solenoid. The common type of magnetizer consists of two iron cores mounted vertically parallel to each other on a horizontal bar to form a U-shaped structure. Two coils of heavy-gauge wire are wound over the cores so that when a current is passed through them the two limbs are of opposite magnetic polarity.

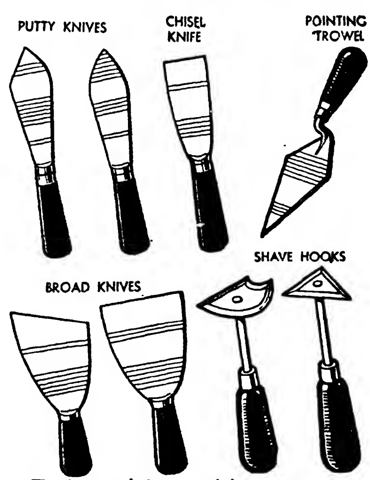
The magnet to be treated is set on the magnetizer with north pole to the south limb and south pole to the north limb. Current is passed through the coils intermittently for a few seconds only, the magnet is then tapped lightly, and the magnetizing process is completed. A keeper is placed across the magnet before it is removed and is kept on until the magnet is assembled with its armature in position.

REMANENCE, see MAGNETIC HYSTERESIS.

REMOTE CONTROL. A method of controlling or adjusting electrical or radio apparatus at a distance by mechanical or electrical means.

RENDERING. The process of covering external and internal walls with lime or cement mortar. When the term is applied to internal plasterwork it is described as *three-coat work,* and the process is known as "render", "float" and "set". The first coat is termed "rendering".

REPAIRS TO SURFACES. To obtain satisfactory results the surface to which any treatment is applied must be sound. In treating *plaster*



Tools used in repairing surfaces.

surfaces, decayed patches of plaster are cut away and replaced by the same type of plastering as was used when the work was first done.

Cracks in the surface, caused by vibration or settlement of the structure, and other small faults must have all the loose material removed by raking out with shave hooks and dusting, the remaining cavity being then painted with good-drying thin oil paint to overcome excessive porosity. When dry, the cavity is filled with stopping made by mixing together equal dry quantities of Keene's or similar hard wall plaster and whiting, which is then worked into a stiff paste by the addition of water; it is pressed well into the cavity and levelled off with a broad knife which, with other appropriate tools, can be seen in the illustration. As soon as the surface of the stopping will stand the passage of the brush it is painted with the same type of paint as that used in the preparation.

On *timber* surfaces decayed wood is cut away and replaced by sound, well-seasoned timber, which should be immediately primed. Nail holes, shrinkage cracks etc. are filled with a stopping made from genuine paste white-lead, a little paste drier and dry whiting worked into a stiff paste. This is pressed well into the cavities and any surplus stopping removed from the surface with a putty knife. No stopping should be undertaken until the priming coat of paint is dry.

REPULSION MOTOR. An electric motor of the single-phase commutator type. See MOTOR.

RESIDUAL MAGNETISM. The magnetism in an electromagnet which remains after the exciting force has been taken away. If there were no residual magnetism in a self-excited generator, the voltage could not build-up.

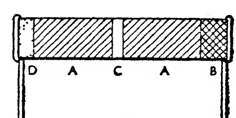
RESINS. Formed by the exudation of sap from growing timbers, chiefly coniferous, which have been damaged; oxidation causes the liquid to harden. Fossil resins obtained from the ground upon which forests formerly stood are the most valuable; they are difficult of solution but, with heat, can be made to form a union with linseed oil. Similar resins of more recent formation are soluble in turpentine. Resins are used in the fabrication of varnishes to improve the gloss and to reinforce the oil content so that a thicker, harder film, which is more resistant to water, is obtained.

RESISTANCE. Symbol: R. The property of a substance which opposes the passage of an electric current through it. The energy expended in making the current flow appears as heat. The practical unit of resistance is the ohm (q.v.). Resistance is proportional to length and resistivity (q.v.), and inversely proportional to cross-section area. See OHM'S LAW.

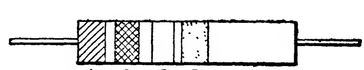
RESISTANCE COLOUR CODE. A system of marking radio resistors so as to indicate their nominal ohmic values. The colours used by British manufacturers to designate the different numbers are as follows:—

0 Black	4 Yellow	8 Grey
1 Brown	5 Green	9 White
2 Red	6 Blue	±5 per cent Gold
3 Orange	7 Violet	±10 per cent Silver
		±20 per cent No indication

The illustration shows two types of resistor in common use and the



(a)



(b)

Method of calculating values of resistors of which two types are shown:

Type (a)	*Type (b)*	*Colour Indicates*
Body A	Band A	First figure of resistance in ohms.
End B	Band B	Second figure.
Band or Dot C	Band C	Number of cyphers
Band or Dot D	Band D	Tolerance.

method of interpreting the colours.

Thus, for example, a resistor with radial leads (type *a*) and having a red body, green end or tip, and yellow band or dot, would have a nominal value of 250,000 ohms. A gold band or dot at its opposite end would indicate that its exact value was within ± 5 per cent of this. A resistor with axial leads (type *b*) of the same ohmic value and tolerance would have bands of colours red, green, yellow and gold, in that order.

RESISTANCE LOSS, see COPPER LOSS.

RESISTANCE WELDING. A welding process in which the two pieces of metal are brought into contact and made to conduct a current of electricity. The joint, being the high-resistance part of the circuit, rapidly heats up, and when a welding temperature has been reached the parts are mechanically forced into intimate contact and the current switched off.

This mechanical force, which is termed the upset pressure, consolidates the weld. It should be noted that in the case of resistance welding the sole function of the current is to provide the heating, the actual weld being made by the upset pressure.

Resistance welding is found commercially in four main groups or classifications, the principle being exactly the same in each. These are: Spot welding, Seam welding, Projection welding and Butt or flash welding.

Spot Welding. In this case plates are overlapped and laid on a fixed electrode and a moving electrode then pressed on top; thus the plates are part of the electrical circuit. Spot welding (q.v.) may be used to join plates up to about $\frac{3}{8}$ in. thick from the lightest gauges, and although most work is done on mild steel, nearly all materials may be welded in this way.

Small welding sets powered by motor car batteries are used by dental mechanics to weld thin stainless material for artificial dentures. If a continuous series of closely spaced spots is made, this is generally called Stick Welding.

Seam Welding. This is exactly the same as spot welding, except that the electrodes are now two wheels and thus plates or sheets may be fed between the wheel electrodes and a continuous linear liquid-tight weld obtained.

Projection Welding. A form of spot welding often used where a number of welds can be made simultaneously by one stroke of the welding electrodes. To effect this, small projections are raised on the parts to be welded and the electrodes are fitted with broad faces. The welds occur only at the projections.

Butt or Flash Welding. These two processes are not really the same. Butt welding, the older form, is true resistance welding, and is still used for joining small-diameter bars and wires.

In this, two bars or tubes of similar section are brought together, supplied with a heating current and, when at a welding temperature, forced together by an upset pressure. A finished butt-weld looks rather like a plumber's "wiped" joint on a lead pipe.

In *flash* welding the bars or tubes to be joined are held as above, but the ends are brought into gentle contact, thus forming an arc which provides the heating agent, rendering the ends of both bars molten.

In this way, when welding temperature has been attained, the upset pressure is sharply applied and the weld completed. Owing to the reduction in metal heated, when compared with the pure resistance method the finished flash weld has a different appearance. It should be noted that flash welding is not really a resistance process.

RESISTIVITY. Symbol: ρ. The electrical resistance per unit cube. It is the resistance between opposite faces of a cube having sides of unit length (i.e. 1 in. or 1 cm.). The value depends on temperature. It is 1·6 microhms per inch cube for copper at 0 deg. C. See also TEMPERATURE

COEFFICIENT. Synonym: Specific Resistance.

RESISTOR. An electrical-circuit component designed to possess resistance (q.v.).

RESONANCE (Chemistry), see MESOMERISM.

RESONANCE (Radio). A phenomenon occurring in an electric circuit when its inductive reactance is equal to its capacitative reactance. For any fixed value of inductance and capacitance, irrespective of whether they are connected in series or parallel, this condition arises at one particular frequency only and, in radio-communication, is the basis of tuning (q.v.).

Mathematically, resonance occurs when $2\pi fL = \frac{1}{2\pi fC}$. A little rearrangement of this equation gives $f = \frac{1}{2\pi\sqrt{LC}}$ where f is the resonant frequency of a circuit in cycles per second, L and C being inductance in henrys and capacitance in farads respectively. See OSCILLATION.

RETAINING WALL. A wall designed to withstand the lateral pressure of the adjacent earth and to prevent it from sliding. Retaining walls may be built of brick, stone, mass concrete, or reinforced concrete.

Resistance to sliding under very heavy thrusts is often obtained by forming a mass of brick, stone, or concrete so that the weight of the wall is sufficient to resist the sliding tendency. Reinforced concrete retaining walls, being light in weight compared with those constructed of mass concrete, are constructed so as to form a monolithic structure comprising a base platform and vertical wall, and are designed to provide resistance to overturning.

RETROACTION. See REACTION.

REV. COUNTER. An instrument more correctly called a tachometer, used to measure the rate of revolution of an engine. The simplest form of tachometer is the centrifugal type, the essential part being a set of governors similar to those fitted to some stationary steam engines or a gramophone; they consist of two flyweights connected by links to two collars on a spindle, one collar being fixed while the other is free to slide up and down the spindle.

Between the two collars is a spring, which constrains the flyweights from moving away from the spindle. The pointer indicating the revolutions per minute is connected to the free collar through a suitable system of gearing. The spindle, which is free to rotate, is driven by the engine through a flexible drive, and owing to the centrifugal force acting on them the weights move away from the spindle, and, in so doing, compress the spring.

The amount the weights move, and consequently the movement of the free collar which is geared to the pointer, is a function of the rate of rotation of the spindle. It is thus possible to calibrate the instrument to indicate the revolutions per minute of the engine.

The most common forms of tachometer in use on aircraft at the present time are of the electrical distant reacting type. These work on several different principles, but in lay-out they all consist of some form of generator housed in the engine nacelle, and driven by a flexible drive from the engine. The indicator unit in the cockpit is connected by electric cables to the generator.

REVERSAL SPEED. Owing to the effects of aero-elastic distortion, it is found that above a certain speed the controls of an aeroplane produce the opposite effect to that which they produce normally.

Ailerons are most prone to reversal which occurs in the following manner. Consider, say, the right-hand aileron; if the control stick is moved to the left the aileron moves down, which in conjunction with the up-going aileron on the opposite side produces a roll to the left. In moving down, the aileron alters the effective camber of the wing, and generates an additional aero-dynamic movement which twists the wing, depressing the leading edge. This reduces the angle of attack of the wing and the consequent loss of

lift gives a rolling movement in the opposite direction to that produced by the aileron.

For a given aileron angle the aerodynamic twisting moment is proportional to the square of the speed of the aeroplane, while the moment resisting it, owing to the torsional stiffening of the wing, is unaffected by the speed, being proportional only to the amount of twist. Thus, as the speed increases, the wing twists more and more as the moment producing the twist builds up faster than the moment resisting it. Thus at some speed, called the reversal speed, the rolling moment due to the wing twist, is exactly equal to the rolling moment produced by the ailerons, so that they are ineffective.

Above the reversal speed the rolling moment due to the wing twist predominates, and if the stick is put over further to the left the aeroplane will roll to the right and vice versa.

REVOLUTION COUNTER, see Rev. Counter.

REYNOLDS' NUMBER. The drag of a body moving through a fluid (air in the case of an aeroplane) is equal to a coefficient depending on the shape of the body, multiplied by the density of the fluid, the square of a linear dimension of the body, and the square of the velocity of the body through the fluid.

This, however, is true for only a particular value of what is called the Reynolds' number, which is given by:

$$RN = \frac{Vl}{\nu}$$

where V = the speed of body through the fluid
l = some convenient linear dimension of the body
ν = the coefficient of kinematic viscosity of the fluid.

The practical effects of Reynolds' number are, first, that the drag coefficient of an aeroplane, deduced from tests on a model in a wind tunnel, will not necessarily enable us to predict the drag of the full-sized aeroplane because the Reynolds' number will be different for the two cases due to the change in the volume of l, and the value of the drag coefficient will probably have changed; and, secondly, that it will vary with speed because the Reynolds' number will increase with increase of speed.

The change in drag coefficient, together with similar kinds of effect on lift and moment coefficients, is called scale effect. In general, with increase in Reynolds' number the drag coefficient will tend to decrease, the maximum lift coefficient will increase, while the moment coefficient will probably be little affected.

It is to enable tests to be carried out in a wind tunnel at the same Reynolds' number as on the full-size aeroplane in flight, and so to avoid scale effect, that the variable density wind tunnel was invented. In it the air in the working section is raised to a pressure of about twenty atmospheres; this has the effect of reducing the value of ν to compensate for the lower value of Vl obtainable in the wind tunnel because of the reduced dimensions of the model compared to those of the full-size aeroplane, and the lower wind speeds attainable.

R.F., see Radio Frequency.

RHENIUM (Re). Atomic no. 75; atomic wt. 186·31. A metallic element which resembles manganese, and can be extracted from molybdenite and some copper ores. The metal has a density of 21·4 and melts at 3440 deg. C. It forms four oxides, Re_2O_3, ReO_2, ReO_3 and Re_2O_7.

RHEOSTAT. An electrical circuit component designed to possess a variable resistance. See Potentiometer.

RHODIUM (Rh). Atomic no. 45; atomic wt. 102·91. A hard, white metal allied to platinum. Its density is 12·1 and it melts about 1940 deg. C. It is very resistant to corrosion, and rhodium plating is used to protect articles of silver. It is trivalent.

RIB (Aero. Engineering), see Wing.

RIBBON MICROPHONE (Radio), see Microphone.

RIDGE. The highest part of a pitched roof or the junction where the upper parts of the rafters meet.

The *ridge board* is the piece of timber, from 1 to 1½ in. thick, against which the tops of the rafters are jointed. The *ridge covering* may be of sheet lead, dressed over a wood roll, which is fastened to the top edge of the ridge board, or covered with specially formed ridge tiles. The latter are bedded in mortar on the roof covering, the tiles being butt-jointed or lap-jointed, and the joints pointed in cement.

RIFFLER. An abrading tool faced like either a rasp (q.v.) or a file (q.v.),

Riffler used for shaping wood.

but, as shown in the illustration, curved in its length for shaping concave work.

RING MAIN. An electric main which starts and ends at the same point. If there is a number of consuming points in the run of the ring main, supply is maintained at all these points when the main is broken in any one place, because each load point may be fed from either direction. In normal operation, a heavily loaded point may be fed from both directions at the same time.

RISERS (Carpentry), see STAIRS.

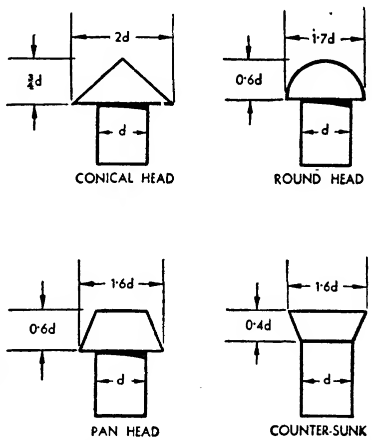
RISERS (Foundry Work), see RUNNERS AND RISERS.

RIVETING. The process of joining two pieces of metal together by inserting a plug of metal or rivet, through two corresponding holes, and hammering or squeezing the metal plug so that it expands and fills the hole, both ends becoming larger than the hole through which the plug protrudes.

In practice it is usual to prepare rivets with one end already bulged, or formed into a definite shape or head, so that the hammering need take place at one side only of the joint. The rivet is held in position by a weight, or dolly, pressed against the head, while the other end of the rivet is hammered-up and finally "buttoned" with a suitable tool. There are several forms of rivet head, but those most commonly used are the snap and countersunk. See RIVETS.

RIVETS. One of the principal means of fastening together permanently the various portions of metal in a structure. They are inserted either hot or cold, according to the nature of the job and the materials concerned, and are driven home by hammering or by hydraulic pressure. Hammering or pressure is also used to form simultaneously a head on the plain end of the rivet.

The commonest forms of rivet are shown in the illustration and include those having a conical head ("steeple") and those with a spherical or "round" head; other very common types have either "pan" heads (called "cone-heads" in the U.S.A.) or "counter-sunk" heads. The proportions of the



Four common types of rivet showing method of calculating correct sizes.

rivet heads are given in terms of the diameter *d* of the rivet itself. To allow enough material to form the rivet head and also to fill the clearance in the hole, the length of the rivet should protrude beyond the plate by about 0·75 *d* for a counter-sunk head and about 1·3 *d* to 1·7 *d* for the other types of head.

If rivets are made of the same material as the plates, the danger of corrosion by galvanic action will be minimized. Riveted joints in plates

are of several types, classified as *butt* joints (if the edges of the plates to be joined are abutting) and *lap* joints (if the edges of the plates overlap). For extra strength two rows of rivets are often used ("double-riveted") or even three ("treble-riveted").

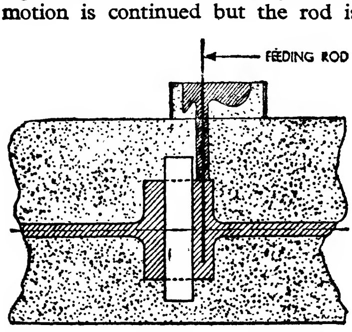
Butt joints are held together by additional plates called *cover straps*, the rivets passing through them as well as the plates; sometimes a single cover strap is used, and sometimes double cover straps, i.e. one strap above and one below the abutting edges of the joint.

R.M.S. VALUE. An abbreviation for the root-mean-square value of an alternating electrical quantity. It is the value in terms of which an alternating voltage or current is normally expressed. See ALTERNATING CURRENT.

ROCKET PROPULSION (Aero. Engineering), see JET PROPULSION.

ROD FEEDING. The operation, in foundry work, of moving an iron or steel rod up and down in a runner or riser until the metal solidifies. The rod should be preheated in the ladle and, as shown in the illustration, is pushed straight down to the bottom of the runner or riser into the casting as soon as the metal is poured. The rod is moved up and down continuously, being worked slowly round the periphery of the gate.

This action breaks up crystals of metal as they form and so promotes feeding by keeping a passage open for liquid metal to pass through. The motion is continued but the rod is gradually withdrawn as the metal becomes pasty.



Method of rod feeding employed in foundry work to break-up crystals.

Large castings may require the addition of hot metal from time to time to keep the feeding head full, and to aid in preventing it from freezing. If rod feeding is adopted, smaller runners and risers may be employed. The operation is used largely for iron castings and only rarely for the non-ferrous metals.

ROD OF BRICKWORK. The standard unit of measurement in building, equal to 272 ft. super of brickwork reduced to $1\frac{1}{2}$ bricks thick. A rod of reduced brickwork contains approximately 4330 bricks and 73 cu. ft. of mortar, and if built with ordinary standard bricks will weigh approximately 15 tons. Brick walls may be reduced to one brick thick and then measured in yards super.

ROLLER BEARING, see BEARING.

ROLLER LEVELLER (Continuous Rolling). A machine used in sheet-metal work for removing wrinkles and depressions, incurred during rolling, from the sheet surface. Many designs are in use, but the basic principle is a double row of staggered rollers, one series above and one below, which operate in a "wringing" fashion, the whole being encased in sturdy housings and the pressure available being individually adjustable.

ROLLER TABLE (Continuous Rolling). The means whereby, in sheet-metal work, rolled material is conveyed between stages prior to coiling. The essential parts are the framework and a suitable number of motor-driven rollers, spaced at intervals.

In intermediary stages, this unit is known as the roller table; on emerging from the hot-finishing stand, as the runout table. In both, the essential design is similar, but in the latter case the speed of rotation is adjusted to suit the rate of travel of the material from the final stand.

ROLL GRINDING. For rolling sheet metal either cold or hot, the rolling mill and rolls must be so designed that the two rolls actually bearing on the sheets provide a

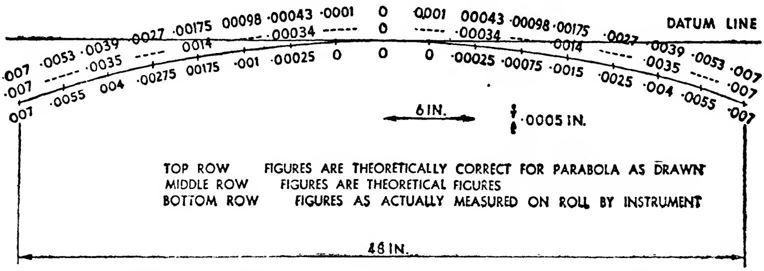


DIAGRAM ILLUSTRATING FORM OF CAMBER ON ROLL

Most accurate cambers on rolls for application to sheet metal are obtained by use of an inclined straight-edge and linkage, giving a camber of parabolic form.

parallel gap between them when the mill is working and loaded.

The top and bottom rolls are unsupported by other rolls, and therefore deflect when sheet is being passed through the mill. If the top and bottom rolls were parallel in their bodies, deflections would cause the sheet to be rolled thicker in the middle than at the edges. For this reason, the top and bottom rolls must be cambered so that the net result of load and deflection is to produce a parallel gap between the rolls in contact with the sheet. In all sheet-rolling mills, therefore, there is the double problem: (*a*) production of accurate, parallel, supported rolls, and (*b*) accurately cambered unsupported rolls.

Until recent years, the finishing of these rolls was in the hands of highly skilled roll turners, but the increasing use of precision-grinding machines for roll grinding has meant the almost total disappearance of the roll finisher.

For cold-rolling of strip, the short, stiff rolls used require only one or two thousandths of an inch of camber, whereas for rolling precious metals and for metal-foil production, even finer and more accurate cambers are required. Camber increases with the width of the rolls as wider sheets are dealt with. For cold rolling especially, present requirements for the highest grade of sheet, ferrous and non-ferrous, mean that the rolls must be ground parallel or cambered with an accuracy, from end to end, of two or three-ten-thousandths of an inch, and much research and development have gone into the design of roll-grinding machines to enable these results to be obtained.

Several methods are employed for producing cambers in grinding machines. One is the use of a cam driven by suitably proportioned gearing operated from the traverse of the work. The most accurate cambers, however, are generally considered to be produced by a cambering mechanism, employing an inclined straight-edge, which, through suitable linkage, generates the required camber, the form of which approximates very closely to a parabola.

Roll-grinding machines are made in two main types. For smaller rolls and for the most accurate work on larger rolls, the roll is traversed past a fixed grinding wheel. For large numbers of the heavier rolls, however, a more compact machine, in which the grinding wheel is traversed along a rotating roll, is very generally in use today, and meets most requirements as regards accuracy.

The chief features that have contributed to the great increase in accuracy in ground rolls are: rigidity in grinding machines; improvements in grinding-wheel spindles; improvements in grinding wheels; improvements in the generating type of cambering mechanism; wide and continuous ranges of speed variations for grinding wheel, work traverse and

work rotation; and removal of grinding debris from the coolant so that it is not carried round again to the grinding wheel to cause a clogging action between the wheel and the work.

The simplest and most effective test of the regularity and accuracy of the ground surface of the roll is obtained by rubbing the surface with a metal surface corresponding approximately to the curvature of the roll. In this way, minute irregularities much too small for measurement are clearly shown. See COLD-WORK and HOT-ROLLING PRACTICE.

ROLLING (Aero. Engineering), see LATERAL STABILITY.

ROLLING AXIS (Aero. Engineering), see AXIS.

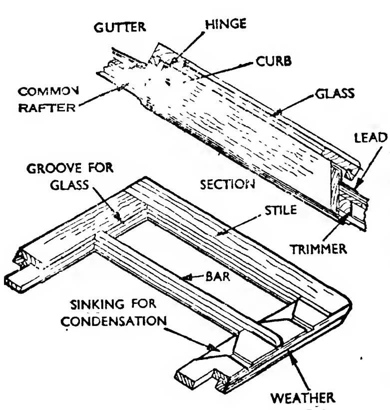
ROOFING FELT. Waterproof material used on the roofs of sheds, out-houses etc., usually made with a fibrous core and impregnated with a bitumastic substance. A thicker and tougher type of felt is often used as a damp course.

For roofing, the felt should not be laid across battens but should have a close-boarded framework underneath. The fewer nails used the better; one method is to give the strips of felt a generous overlap, to shoot-off the rain, and to hold them down with full-length battens laid at right-angles to their length.

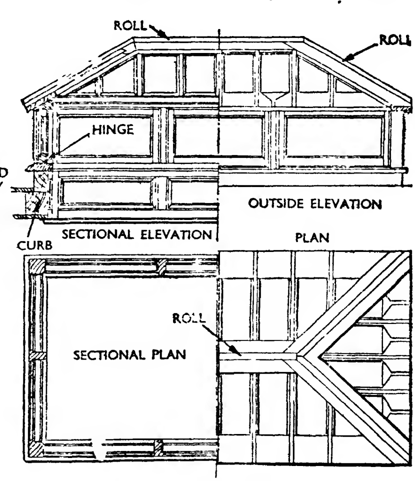
ROOFING TILES. These may be of the varieties known as plain tiles, pantiles and interlocking tiles. Plain tiles are made from brick clays and are provided with projections, known as nibs, for hanging them to the battens, and with nail holes for additional fixing. Tiles are also made of asbestos or cement.

The standard sizes are $10\frac{1}{2}$ in. × $6\frac{1}{2}$ in. × $\frac{1}{2}$ in., with a $\frac{1}{2}$-in. camber to ensure good bedding at the tail. They are usually laid to a $2\frac{1}{2}$-in. lap. A good roofing tile should be tough, dense and vitrified. The durability of the tile and, therefore, its effectiveness, will depend upon its structure and chemical composition.

ROOF LIGHT. A term applied to dormer windows and lantern lights, but chiefly used to define a light or window constructed in connexion with pitched roofs and often termed a sky-light. Openings in timber roofs, or roof lights, are trimmed in the same way as openings in timber



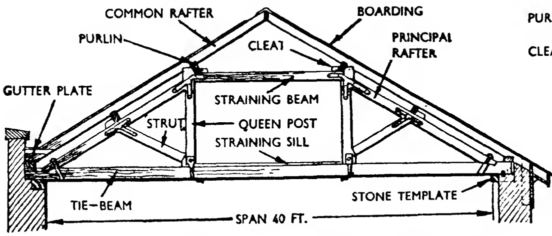
SKYLIGHT

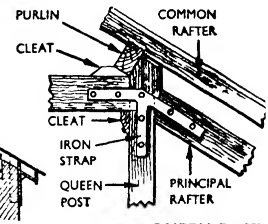


LANTERN LIGHT

FORMS OF LIGHT USED IN ROOF DESIGN

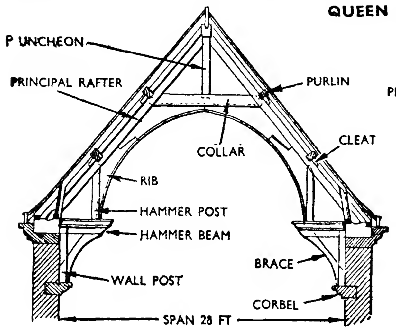
Structural details of typical examples of skylight and lantern light. Skylights are erected above an inclined plane. Lantern lights, in either wood or metal, are more elaborate constructions on flat roofs, usually with patent glazed tops.



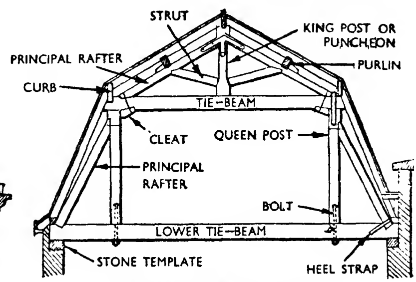


QUEEN POST TRUSS

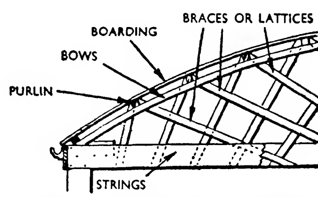
QUEEN POST DETAIL



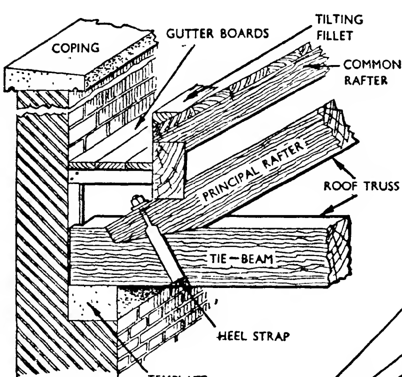
HAMMER BEAM TRUSS



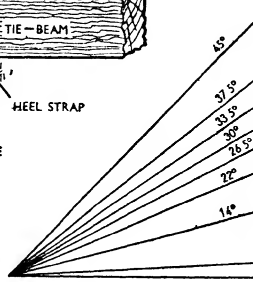
MANSARD OR CURB TRUSS



BELFAST OR BOWSTRING TRUSS



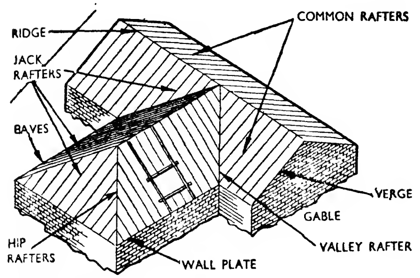
GUTTER DETAILS



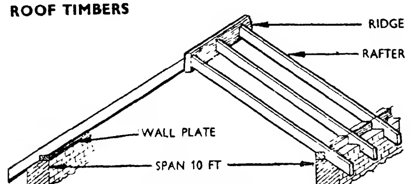
MINIMUM PITCH	MATERIALS
1/2	THATCH, SHINGLES
1/2.4	PLAIN TILE
1/3	SMALL SLATES
1/3.5	ASBESTOS TILES
1/4	ORDINARY SLATES, PAN TILES
1/5	LARGE SLATES, ROMAN TILES
1/8	CORRUGATED SHEETS, FELT
1/80	LEAD, ZINC, COPPER

ROOF PITCHES

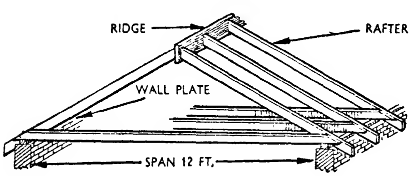
Details of construction of some common types of wood or composite roof in general use in Britain. Differences in pitch can be clearly seen, these being largely dependent upon the covering materials employed. The diagram of roof pitches elaborates this point. Inclination up to 20° from the horizontal is treated as a flat roof, a covering of metal, felt or bitumastic sheets being employed.



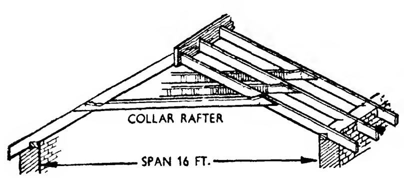
ROOF TIMBERS



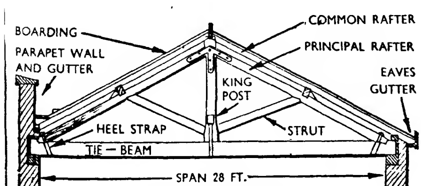
COUPLE ROOF



COUPLE CLOSE ROOF



COLLAR TIE ROOF



KING POST TRUSS

Further examples show the principles of roof construction. Lettering to diagrams on this and the preceding page shows terms used in roofing and positions of the various members.

floors, the rafters at the sides of the opening being increased in thickness according to the number of rafters interrupted by the opening.

Roof lights are of three types: skylights, dormers and lantern lights. A skylight is parallel to the surface of an inclined roof. It consists of a glazed frame raised above the roof surface by a curb surrounding an opening trimmed in the rafters. There are variations, but the principles shown in the illustration are generally applicable. The chief difficulty is to keep them watertight, and lead flashings (q.v.) are required round the curb. The light is held open by means of a stay, fixed to the sash, which engages with a pin on the curb. A *dormer* is a vertical window projecting above a sloping roof. The details can be very varied, as architectural features, but the chief difficulties lie in preparing to receive the glazed frame. The top may be flat and covered with lead or zinc, or it may be pent-shaped with tiles or slates. In exposed positions the vertical light is sometimes framed within the roof. In this case it is called an internal dormer.

Lantern lights are erections on flat roofs, and they may be elaborate structures in wood or metal. The usual type is shown in the illustration. Several of the casements are arranged to open. The top is formed of four frames mitred at the hips, with details similar to those for the skylight. Usually, the top is formed of patent glazing even when the remainder is of wood, because there is more certainty of making it watertight. See LANTERN LIGHTS and LAYLIGHTS.

ROOFS. There are two main types of roof: flat and pitched. The surface of a flat roof will have only a slight inclination, or a sufficient amount of fall to allow the rainwater to flow into the outlets, whereas the surfaces of pitched roofs will vary in inclination from an almost flat roof to one of extreme pitch. The angle of pitch is usually governed by the type of covering material, but the architectural design of a building may be the

deciding factor. There are several types of pitched roof, known according to their outline or the manner in which they are framed.

The various types of roof in carpentry are distinguished as: *single*, when only common rafters are used; *double*, when purlins are added; and *trussed*, when structural frames are placed at intervals to carry the purlins and common rafters. Single and double roofs are usually confined to houses and small buildings, but trussed roofs may be designed for nearly any size of building. Roofs are also named according to the shape, the arrangement of the constructional members, the name of the original designer, or the materials forming the covering. The types of wood or composite roof in common use in Britain are: Belfast or bowstring, couple and couple-close, collar and collar beam, flat, hammer beam, king post, mansard, lean-to, queen post, north light and scissors. There are many other types, including registered designs and laminated roofs for large spans, but they are chiefly the work of specialists. The selection of a suitable arrangement depends upon span, pitch, architectural requirements, and type and position of building.

PITCH, the inclination of a roof, is usually controlled by the type of covering. When less than 20 deg. it is usually considered as a flat roof, and the covering is in the form of large sheets, metal, felt or bitumastic materials. The illustration gives the approximate minimum inclinations suitable for the different roofing materials, and the terms used when referring to the pitch. For instance, half pitch implies that the rise is equal to half the span.

LEAN-TO ROOF. This is the simplest form of pitched roof and consists of one inclined side only, like half of the couple roof. It is usually erected against a gable wall. A purlin is included when the length of the rafter is over 8 ft. and the covering is tiles or slates. The tops of the rafters may be built into the brickwork, or fixed to a wall plate supported on strong wrought-iron corbels. The feet of the rafters are bird's-mouthed on to a wall plate, as shown for the couple roof.

COUPLE ROOF. For a small isolated building, or when the span is too big for a lean-to, the couple roof is used. This is the simplest form of *span* roof. As the span increases the thrust from the roof tends to throw the walls over. To counteract this a tie is fixed to the feet of the rafters, which also serves as a ceiling rafter.

COLLAR-TIE ROOF. A useful small-span roof with good head-room. The collar, which is from one-third to half-way up the rafters, prevents any sagging under the weight of the roof covering.

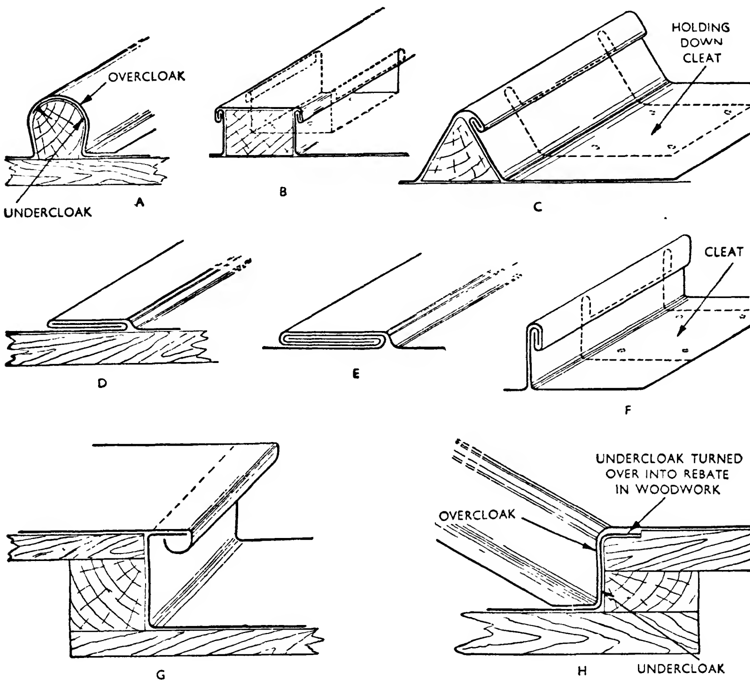
ROOF TIMBERS. The sketches show the terms used in roofing, and the relative positions of the various members.

JACK RAFTERS are like common rafters, but they are shorter and have a splayed cut at the foot to fit on the *hip* rafter for an external angle, and on the *valley* rafter for an internal angle. The *verge* is where the roof ends on a gable wall. In this case the ends of the roof timbers are often covered with a barge board, which forms a decorative feature of the gable. See PITCHED ROOF.

ROOF TIMBERS, see JOINTS and ROOFS.

ROOFWORK (Plumbing). The fixing of weatherings, such as aprons and flashings, and the covering of flat roofs and gutters with sheet lead, copper or zinc. Owing to the fact that lead expands more than it contracts, sheet lead is laid in sizes not exceeding 20 sq. ft. in area, and is so jointed that free expansion can take place. Fig. 1 illustrates the wood roll, which is used in joining the sections on flat roofs, gutters and dormer tops. The welt, a joint used in vertical leadwork, is also shown.

Drips in sheet leadwork should not be less than 2 in. deep. The principle is that of an undercloak and overcloak, also shown in Fig. 1. The undercloak is laid in, and the top edge



LEAD, COPPER AND ZINC JOINTS IN ROOFWORK

Fig. 1. Diagrams above show: A lead-covered wood roll, B rectangular wood roll or batten seam in copper, C conical roll in copper, D single-welt lead joint, E double lock welt (copper cross-joint), F section and elevation of standing seam in copper, G drip in sheet zinc and H section of drip in lead gutter.

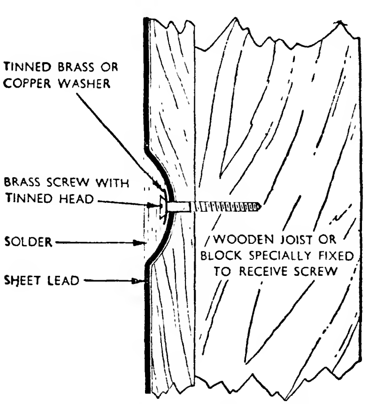


Fig. 2. Soldered dot for securing lead to vertical surfaces, showing the circular dishing cut in the woodwork and solder covering head of screw.

of the vertical part dressed into, a rebate cut in the woodwork. This rebate is cut to the exact thickness of the lead so that the lead lies flat with the surface of the wood. The overcloak is worked down the drip and finished with a lap on the bottom gutter. Similar methods are used with the wood-roll joint. Double welts are made by interlocking a single welt turned on the two pieces of lead to be joined.

For fixing lead to vertical surfaces, the soldered dot illustrated in Fig. 2 is used. The sheet lead is dressed into a circular dishing cut in the woodwork, and secured by means of a tinned copper washer and brass screw, which is then covered with solder by flush wiping. A lead dot is used for

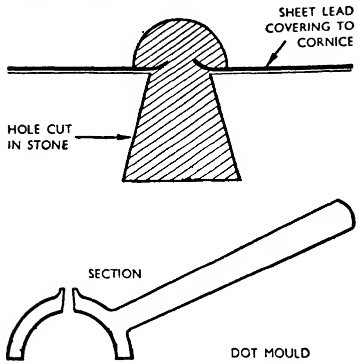


Fig. 3. Cast lead dot as used for fastening sheet lead to stone cornices, with section of dot mould for pouring molten lead into hole in stonework.

fastening sheet lead to stone cornices, as shown in Fig. 3. The hole in the stonework is mortised back to prevent the dot lifting, and molten lead is poured in through a dot mould similar to that shown in the illustration.

Permanent and water-tight lead-to-stone fixings are made by turning the upstand of a sheet of lead into a groove

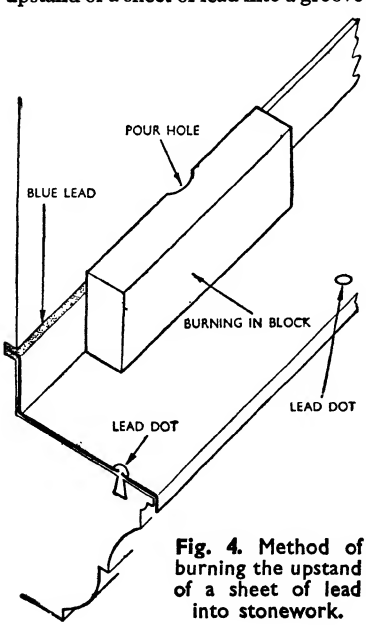


Fig. 4. Method of burning the upstand of a sheet of lead into stonework.

cut into the stonework and "burning in". The method, which consists of filling the groove with molten lead in sections by means of a burning-in block, after which the lead is tightened up gently with a caulking tool, is shown in Fig. 4.

Sheet lead is also used for weathering the top of a sloping, or pitched, roof, where slates or tiles are the roofing material (Fig. 5). The lead ridge or hip is secured by means of lead bale tacks to the ridge or hip

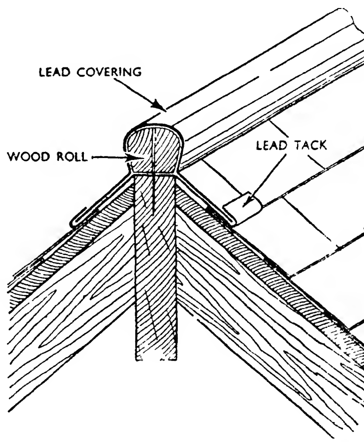


Fig. 5. Lead-covered ridge, or hip, roll for weathering top of tiled roof.

timber before the wood roll is fixed, and the lead should extend far enough down the slope of the roof to cover the two top courses of slates or tiles.

Copper and zinc are used alternatively for the same purposes as lead, and are fixed in a similar manner, with wood rolls and welted seams. Other seams in sheet-copper are known as the standing seam, the conical roll, and the rectangular or batten seam. Copper suffers less expansion than lead, and that most often used for roof coverings is of 23 or 24 Standard Wire Gauge, and is obtainable in sheets ranging from 6 in. to 4 ft. in width, up to 14 ft. in length.

Zinc used for roofwork is usually of from 14 to 16 gauge. Lead can be

obtained weighing from 4 to 7 lb. per sq. ft., and in sizes up to 9 ft. in width and 50 ft. in length. See CHIMNEY WEATHERING and FLASHING.

ROTARY CONVERTER. An electrical machine in which a single armature is connected both to a commutator and to slip-rings. It is normally used for converting A.C. to D.C., but, if required, it will operate the other way round.

ROTARY FURNACE. A special type of furnace used in foundry work mainly for the manufacture of high-strength and other special cast-irons. It consists of a cylindrical body with coned ends, into which the metal is charged.

Firing is effected by pulverised coal, oil or gas, a burner being fitted at one end of the body and the exhaust gases led away from the other.

The body can be rotated slowly, and in this way the heat stored in the lining is transferred to the metal by contact. Very high temperatures, over 1600 deg. C., are possible, and the composition of the melt can be closely controlled. The running costs are somewhat greater than in cupola melting. See CUPOLA.

ROTARY PRESS, see PRINTING MACHINES.

ROTATING MAGNETIC FIELD. A magnetic field, produced by a polyphase winding, which is similar in character to a field which would be produced by a straight magnet rotating at synchronous speed. See MOTOR.

ROTOR (Aero. Engineering). The rotating wings of gyroplanes and helicopters. Rotors are similar to the wings of a normal aeroplane, except that they are longer in relation to their width, and thinner. When the rotors are spun lift is generated in the same way that a propeller generates thrust.

In the gyroplane the rotor is kept spinning by the forward motion of the machine, which is pulled through the air by an ordinary propeller. The helicopter, however, has no propeller, the engine being connected to the rotors, which provide both lift and the force to propel the machine through the air.

ROTOR (Elec. Engineering). The part of an electrical machine which rotates.

ROUGH BRACKET (Carpentry), see STAIRS.

ROUGHCAST. A form of covering for external wall surfaces. A rendering coat of cement and sand is first applied followed by a second coat, which is brought to a true surface. While this is still wet, fine shingle, gravel, or spar, mixed with cement or lime, is thrown on to the surface, particles becoming partly embedded during the process.

ROUGHING TRAIN. The first rough-passes in the continuous process of sheet-metal work designed to reduce the metal thickness (from the slab), true the sides, and clean the surface by means of roll pressure plus hydraulic spray. It is usual to have four roughing-mill stands (which are *not* continuous in operation) along with such scale breakers and edging rolls as are required. Each mill stand is a complete unit of housings, rolls, pinions and drive.

R.P.M. Revolutions per minute. See INTERNATIONAL POWER.

R.P.S. Revolutions per second.

R.S.J. In building, a recognized abbreviation for rolled-steel joist.

RUBBER. The solid matter, also known as indiarubber, obtained from the latex or juice of *hevea brasiliensis*. When first prepared it is plastic and inelastic, but when treated with sulphur it becomes hard and elastic. The process is called vulcanization. Rubber is a hydrocarbon apparently formed by the condensation of molecules of isoprene.

RUBBER TOOLS (Sheet-Metal Work). Rubber is being increasingly used in press- and drop-stamp work, broadly speaking in two ways. With large hydraulic presses up to a ram pressure of 5000 tons, the top tool consists of a solid rubber pad, encased and vulcanized in position. Forming, shearing and flanging operations are quite possible by the employment of suitable lower tools.

It was first thought that in using rubber tools in such machines increased power would overcome operating difficulties, but a new technique is rapidly growing whereby the varying hardness (and other physical properties) of rubber are being more fully realized, with the result that the largest presses are no longer considered necessary for complicated or difficult work. In drop stamping, rubber is generally used to soften a severe draw in hard metal, such as Monel. Pads are placed on the blank, and after each blow one pad is removed, the shape being therefore achieved by easy stages. See DROP STAMP.

RUBIDIUM (Rb). Atomic no. 37; atomic wt. 85·45. An element of the same group as sodium and potassium; it is silvery-white, density 1·52, melts at 39 deg. C., boils at 696 deg. C. It is monovalent and reacts easily with water, forming the monoxide, Rb_2O.

RUDDER (Aero. Engineering), see EMPENNAGE.

RUDDER VOLUME. A non-dimensional coefficient relating the size of the vertical tail (i.e. fin plus rudder) to the remainder of the aeroplane. Thus we have:

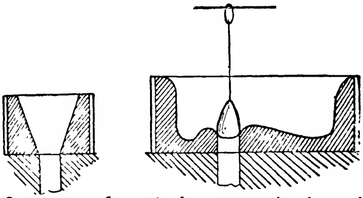
$$\text{Rudder volume} = \frac{l_r s_r}{Sb}$$

where l_r = distance from C.G. of aeroplane to centre of pressure of fin and rudder.
s_r = fin and rudder area.
S = wing area.
b = semi-span.

It is in effect a rough measure of rudder power, and it is used to estimate whether or not a new design of aeroplane has sufficient vertical tail area, by comparing the value of its rudder volume with those of previous designs whose characteristics in flight are known.

RUNNER BUSH. A reservoir, also known as a pouring basin, formed on the cope in foundry work to receive the molten metal and from which it flows into the gate. If the metal is poured rapidly, so that some metal is always retained in the bush shown in the accompanying illustration, the entry of dross into the mould is largely prevented. A simple conical basin, formed by ramming sand in a short piece of iron pipe, is used for small castings.

A rectangular box is better for large castings. The shape of the bush is modified, the opening to the runner



Sections of conical runner bush and (right) runner bush with stopper.

being to one side and above the level of the well into which the metal is first poured. A runner stopper used with this type of bush helps to ensure that no dross enters the mould.

RUNNERS AND RISERS (Foundry). A runner, or down-gate, is a passage cut in a mould through which the metal flows from the runner bush into the mould cavity. A riser connects the mould cavity to the top of the mould, thus enabling the moulder to see when the mould is full.

Both runners and risers also serve to feed the casting, and their respective position must be chosen to obtain the best effect. Runners are usually attached to, or lead directly into, a heavy part of the casting. Risers usually lead off from a high part of the casting, irrespective of whether it is thick or thin. Their use in this manner prevents the setting-up of air pressure which might obstruct proper filling of the mould, and reduces the strain imposed at the moment when the mould becomes filled.

The size of runners and risers employed depends on the type of casting and the metal employed. Thus the non-ferrous metals, with their high shrinkage, need larger runners etc. than cast-iron.

RUNNING AND SLIDING FITS. Different classes of fitting or mating of

two machined surfaces. These belong to the class of cylindrical fits used when two parts of a machine are intended to have relative movement. If the two parts must remain fixed together, without relative movement, then either a driving fit, a force fit, or a shrink fit must be adopted.

For running or sliding fits the difference in diameter between the shaft and the bearing should be sufficient to allow of the existence of a film of lubricant. This tolerance will be governed by the diameter and length of the bearing, by the materials used for both bearing and shaft, and by the purpose and general working conditions of the bearing.

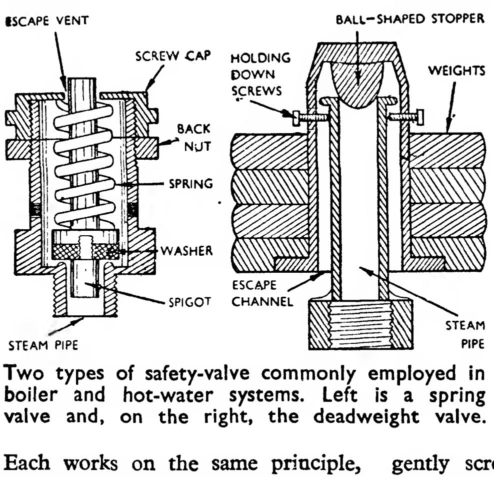
Unless the bearing in question happens to be unusually long, a tolerence of, say, $\frac{1}{1000}$ in. for every inch in diameter of the shaft will suffice. If the spindle or shaft is hardened and ground and runs in hardened and ground bearings, a very small tolerance is needed; the same also applies to the use of bronze bearings with hardened and ground shafts.

The use of high rotational speeds and close running fits has brought about the use of special bearing metals, e.g. certain types of white metal or bronze, which may be used as alternatives to hardened steel. With the exception of the latter material, it has been found that dissimilar metals give better results than like metals in running fits. For sliding fits, however, both shaft and bearings will give good results even if of the same material.

RUTHENIUM (Ru). Atomic no. 44; atomic wt. 101·7. A rare element of the platinum group; it is hard, white and brittle, with a density between 12·2 and 12·5.

It melts at about 2500 deg. C. It is divalent, tetravalent and octavalent, forming oxides RuO_2 and RuO_4 and chlorides $RuCl_2$, $RuCl_3$ and $RuCl_4$.

SAFETY VALVE. An automatic outlet for relieving pressure in a boiler or hot-water system. Two types are illustrated, (a) the spring valve and (b) the deadweight valve.



Two types of safety-valve commonly employed in boiler and hot-water systems. Left is a spring valve and, on the right, the deadweight valve.

Each works on the same principle, that of a loaded plug or flap closing an orifice until the pressure within rises sufficiently to lift the plug. In the spring-loaded type, the spring forces the plug, or spigot, into the steam outlet so that the washer closes the opening, while in (b) the ball-shaped plug is retained in position by means of the weights, the set-screws preventing the valve-top being blown right off.

Safety valves are adjustable, so that they can be set to blow-off at different pressures as the occasion arises, or they can be built to work at one pressure only. The spring-type valve on a hot-water system should be set by unscrewing it until water leaks from the escape holes, and then gently screwing it down until the leakage stops; any further pressure may cause damage to the spring.

Deadweight valves should be ordered to suit the pressure of the particular system in which they are to be used.

SAGE GREEN, see GREENS.

SAILPLANE, see GLIDER.

SAL AMMONIAC. Ammonium chloride, see AMMONIA.

SALIENT POLE. A pole of an electrical machine in the form of a radial projection from the hub or yoke. See POLE and MOTOR.

SALT. The salt found on our tables is sodium chloride (q.v.). Chemists use the word salt to include any substance made by replacing the whole or part of the acidic hydrogen in an acid by a metal or a basic radical.

SALT BATH. A vessel containing a molten salt, used in metallurgy in various heat-treatment operations, the word "salt" being understood in its wider chemical sense.

Salt-bath treatment gives rapid and uniform heating, with ease of temperature control. The following processes are typical:

Light alloy solution treatment, which is carried out in salt baths heated by gas, oil or electricity. The salt is either a mixture of 54 per cent potassium nitrate with 46 per cent sodium nitrate (melting point of mixture 220 deg. C), or pure sodium nitrate (melting point 310 deg. C). A low-carbon steel container holds the molten salt, in which the light-alloy sheet or pressings are immersed. The correct temperature (about 495 deg. C. in the case of duralumin) must be rigidly adhered to, since overheating results in cracks and blisters. In the case of thin sheet, a few minutes' soak before quenching will suffice (see NORMALIZING).

The work must be clean on immersion, since grease or dirt will accelerate the decomposition of the molten nitrate into nitrite, thus:

$$2NaNO_3 = 2NaNO_2 + O_2$$

Sodium Nitrate Sodium Nitrite Ox'g'

The *nitrite* content of the bath should be tested by a monthly analysis, since a rapid increase in the amount of nitrite indicates the presence of contaminating substances or of corrosion of the container at some local "hot spot".

Hardening steel tools. Salt-bath hardening under the right conditions eliminates scaling and de-carburization. For high-speed steel tools the electrode type of salt bath is widely used. The salt is usually barium chloride or one of the proprietary compositions sold for the purpose. It is melted in a bath lined with a special refractory material which will resist the corrosive action of the molten salt at the high hardening temperature required (1250 to 1300 deg. C.). To start-up, a pair of auxiliary electrodes with a piece of carbon wedged between them are used to melt the first layer of salt.

Further salt is added until the main electrodes can be used to maintain the temperature. This method is necessary because the solid salt does not conduct electricity.

After immersion for a predetermined period, the steel is quenched in oil or air (or sometimes in a second salt bath at 600 deg. C.). The final tempering or "secondary hardening" at about 600 deg. C. is then carried out.

Cyanide case-hardening. This rapid method of case-carburizing is specially useful for small parts. The salt, which is mainly sodium cyanide, is melted in a pot constructed of calorized mild-steel plate. The work to be case-hardened is put into a ladle or basket and immersed for a short time in the molten cyanide at about 950 deg. C. The parts are then oil-quenched and the case is finally hardened by reheating to 760 deg. C. for a few minutes and quenching in water.

Cyanide case-hardening gives a clean, bright finish, with a uniform case which merges gradually into the core, and shows little tendency to crack or spall.

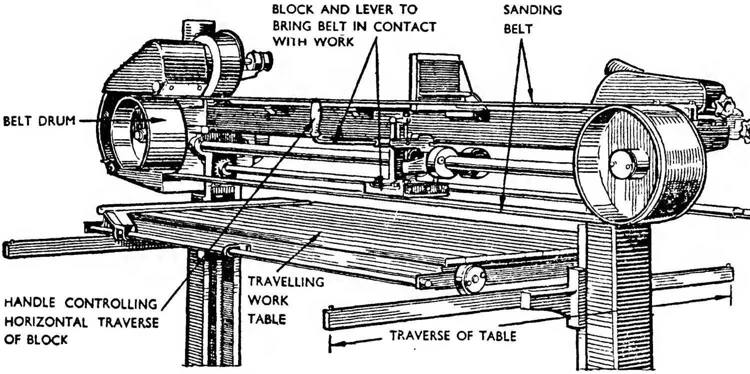
SALT-BATH BRAZING, see BRAZING.

SAMARIUM (Sm). Atomic no. 62; atomic wt. 150·43. One of the rare-earth elements, a grey metal, density about 7·7, very hard, m.p. about 1350 deg. C. It is trivalent and

divalent. Its compounds are unimportant.

SAND (Metallurgy), see MOULDING SANDS.

SANDERS. Sandpapering machines designed for nearly every kind of work, from doors and floors to small cylindrical work. They may be fixed or portable, and are distinguished as drum, bobbin, belt, disk and dowel. A single-belt sander as used in the furniture trade is illustrated. Drum sanders for panelled framing, etc., may have up to eight drums, and sandpaper both sides in one operation.



SINGLE-BELT, STRAIGHT-PEDESTAL SANDER

This machine, of a well-known type extensively used in the furniture trade, is fitted with a self-contained dust-extracting attachment and electric drive.

SAND-LIME BRICK. A brick made by moulding and compressing a damped mixture of sand and slaked lime and exposing the mixture to steam under pressure. Hydrated calcium silicate is formed by the action of the steam, and acts as a cementing agent to bind the grains. The bricks are accurate in shape and size and their arrises are sharp. After pressing, the green bricks are passed into hardening chambers, where they are subjected to a steam pressure of about 200 lb. per sq. in. This process ensures the elimination of free lime.

SAND MIXERS. Machines employed in foundry work to produce sand mixtures in a condition suitable for moulding. They ensure that moisture is evenly distributed throughout the sand, and in this way a minimum may be used. They also cause each grain of sand to become evenly coated with clay, thus improving the bond.

The Chilean Mill is one of the oldest types, and is still to be seen in many foundries, although its use is now largely confined to the making of loam mixtures. Modern types of mixer have the advantage that a minimum of damage is caused to the sand grains. In this way, the uniformity of grain size present in a good moulding-sand is retained and the permeability is not impaired.

SANDPAPER. A name in common use for the various types of abrasive papers, except emery cloth, used by hand or on machines or sanders (q.v.). The abrasive material, which may be aluminous oxide, flint, garnet or glass, is mounted on either paper or cloth, according to its particular use, in sheets or rolls.

Sandpaper for hand use may be of glass or garnet, whilst aluminous oxide, flint and garnet, are used for machine work.

In all cases the abrasive is crushed and sifted to the required grade and attached to the paper by glue, which may be waterproof. The abrasive is spread on the paper, beaten, and the whole is then re-heated so that the

abrasive sinks into the glue and makes contact with the paper.

Glasspaper for handwork is graded, according to the coarseness, as number 0, 1, $1\frac{1}{2}$, fine 2, middle 2, strong 2, $2\frac{1}{2}$ and 3, and is mounted on kraft paper. Manilla paper or white duck cloth is used for machine paper.

The most usual type is flint paper, which is graded from number three 0 to number 4. Garnet paper is graded from 4/0 to 3, and the grades rise by $\frac{1}{2}$ after 1/0. Special types of paper are flour paper, which is graded *oo* and *ooo*, for fine handwork, and garnet paper, which is graded from 7/0 to 1/0.

SANITARY ENGINEERING. That branch of engineering dealing with the removal of waste water and sewage (q.v.).

The most important consideration is the fall (q.v.) of pipes or drainage areas and comparative levels.

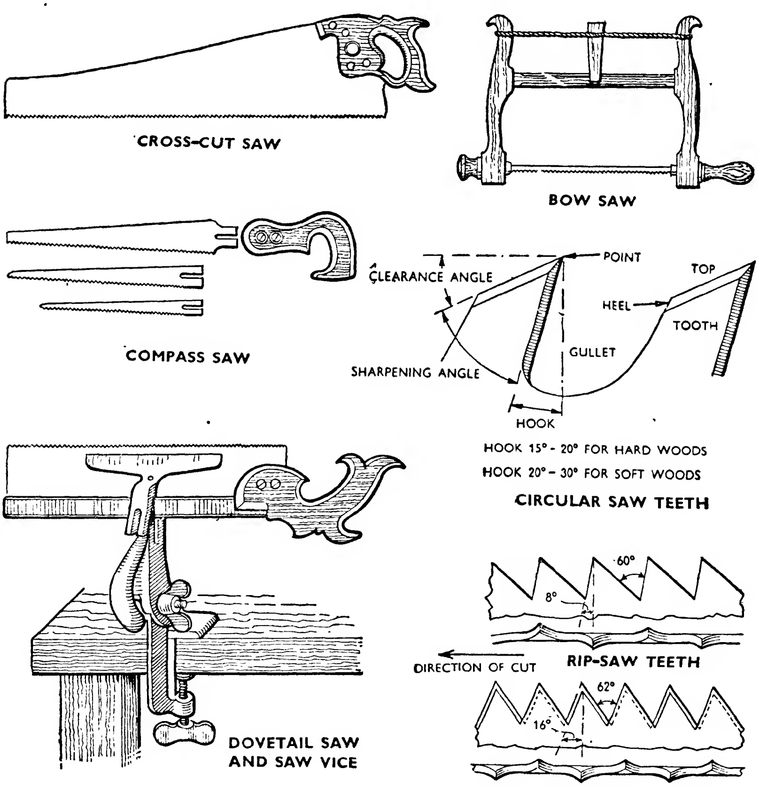
All pipes and fitments should, wherever possible, be self-cleansing, and smooth, or glazed, surfaces are for this reason to be preferred. See DRAINAGE.

SAPELE, see MAHOGANY.

SASH-AND-FRAME WINDOWS, see WINDOWS.

SASH JOINT, see JOINTS.

SASH TOOLS. Round brushes formerly used for painting window sashes and greenhouses. For oil painting they have been replaced by small flat brushes, but they still have



TYPES OF SAW USED BY THE WOODWORKER

Fig. 1. Illustrations above indicate how the teeth and shape vary according to the work for which a saw is intended. Note teeth of cross-cut and rip-saws.

a limited use with distemper. See PAINTERS' BRUSHES.

SATURATION (Elec. Engineering). The magnetic state which is reached when a large change in the magnetizing force applied to a magnetic material produces a very small change in flux. See MAGNETIZATION CURVE.

SATURATION (Radio Engineering). Saturation in regard to a radio valve is a condition arising when the anode collects electrons as fast as they are emitted. Efforts to increase the anode current by raising the anode voltage are ineffective and the valve is said to be operating at voltage saturation.

SAW. A cutting tool with a serrated edge. The types of saw used by the woodworker, some of which are illustrated in Fig. 1, include tenon, dovetail, cross-cut, rip, compass, coping, keyhole or pad, panel and bow saws. The size and shape of the teeth vary for the particular work. Crosscut and rip saws are alike except for the shape of the teeth. The panel saw is shaped like the crosscut, but is smaller and has smaller teeth. Tenon and dovetail saws are for finer work, hence they have thinner blades which are strengthened by stiffened backs. The number of teeth, or points, per inch are approximately as follows: crosscut, 6; rip, 4; panel, 9 or 10; tenon, 10 or 12; dovetail, 14.

Bow, compass, key-hole and coping saws are used for curved work. The blades of the compass and key-hole saws are sufficiently stiff to support themselves, with careful use, but the bow and coping saws are similar to fret saws, and have to be held in tension at each end. All saws should be kept free from rust, and the teeth should be protected by a shield when not in use.

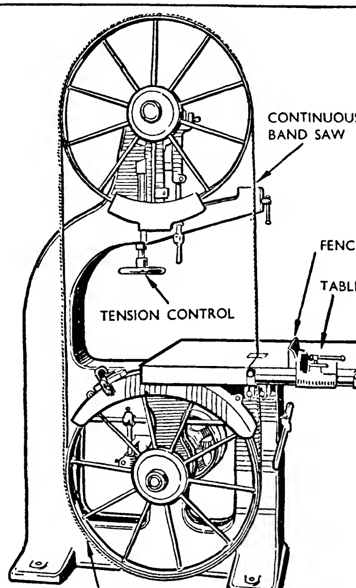


Fig. 3. Band saw. This is one of many kinds of mechanically operated saw.

SAWS, MACHINE. Mechanically operated saws are differently shaped for different purposes. There are circular, band and oscillating saws. Circular saws, see Fig. 2, are described as *cross-cut*, for cutting across the grain, and as *rip-saws*, for cutting along the grain, the cross-cut saws being further distinguished as *straightline*, *mitre* (when intended for cutting obliquely across the grain), *double* or *multiple* (for making two or more cuts in one operation) and *pendulum*. The pendulum cross-cut saw consists of a cast-iron frame, swinging from a point of suspension like a pendulum, with

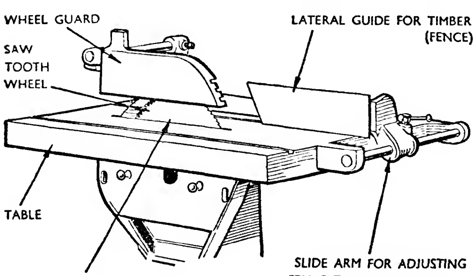


Fig. 2. Shown here are main parts of a typical circular saw, arranged to cut fencing timber.

a circular saw at the end. The saw is pulled across the stationary wood. Band saws vary from large types, for re-sawing and conversion of logs, to narrow ribbon saws for curved work. The general layout can be seen in Fig. 3.

Oscillating saws, which cut with a to-and-fro movement, may be *jigger* or *scroll* saws, which are like fret saws, or they may be heavy frame saws used in conversion. There are also many different kinds of machine saw for specialized work.

SAW-FILE, see FILE.

SAW-TOOTH OSCILLATOR. In radio, an oscillator which produces a voltage rising steadily to a peak and then suddenly collapsing. One of its important applications is in the cathode-ray oscillograph (q.v.). See also TIME BASE.

SCAFFOLDING, see TEMPORARY TIMBERING.

SCALE (Metallurgy). Oxide of iron formed on the surface when steel is heated in an oxidizing atmosphere. The oxygen of the air is the most common oxidizing atmosphere, but carbon dioxide, steam and even carbon monoxide under certain conditions are common agents.

At low temperatures the scale appears rather as a tint or colour on the surface of the steel, varying with increasing temperature from straw to blue and brown and finally black. Above 550 deg. C. the black scale becomes loose and can be readily detached from the parent steel. The term "scale" refers more generally to this loose, black oxide. Its composition corresponds most closely to magnetic oxide (Fe_3O_4).

The iron-oxygen system is very complex; although there are only three authenticated oxides of iron, they dissolve in each other in several series of solid solutions, so that pure oxides are rarely found. The reactions that form the three oxides of iron are as follows:—

$$O_2+2Fe=2FeO$$
$$O_2+4FeO=2Fe_2O_3$$
$$FeO+Fe_2O_3=Fe_3O_4$$

Ingots in soaking pits develop a heavy Fe_3O_4 to Fe_2O_3 scale, which is usually removed by mechanical means.

In rolling operations of bar or slab, high temperature and pressure in presence of water give a hard plate-like scale of Fe_3O_4. Oxides or scale from annealing formed in absence of pressure and water are dry and grainy, usually Fe_2O_3, which increases with temperature and available oxygen. The colour on annealed sheets along the border in this oxide ranges from bright yellow at low temperature to reddish-blue or deep blue at high temperature. See SCALE BREAKER.

SCALE (Plumbing). Encrustation in pipes and boilers arising from the precipitation of lime salts in water. Scale in pipes may lead to stoppage or fracture, while the efficiency of boilers is reduced owing to the layer of non-conducting material between the boiler plate or flue and the water.

Scale may be reduced by passing hard water—that is, water containing carbonate and sulphate of lime in solution—through a water softener before it enters the boiler or hot-water system, or by using the same water over and over again, so that after the initial deposit of lime no further encrustation takes place.

SCALE BREAKER. In sheet-metal work, a two-high mill-stand interposed in the roughing train (q.v.) for the purpose of removing the heavy scale formed during heating of the slab in the continuous rolling process. The mechanism of scale removal is believed to be as follows: cold water impinging on the hot scale causes a reduction in its area as compared with the solid-steel base, and consequent cracking.

High-pressure water might enter these cracks and be immediately converted to steam. The scaly surface is therefore broken up, and high-pressure cold water can then flush the material surface clean.

SCALE EFFECT (Aero. Engineering), see REYNOLDS' NUMBER.

SCANDIUM (Sc). Atomic no. 21; atomic wt. 45·1. A rare element of the aluminium group. The metal has not

been isolated, the compounds show that it is tribasic. It seems that the element is uniform, not a mixture of isotopes.

SCANNING. In television, the process of exploring an image to obtain electrical variations corresponding with the differences of light intensity of successive areas of the image. In the iconoscope (q.v.), the image is scanned by a cathode-ray beam in such a manner that the entire picture is systematically covered by a series of horizontal sweeps, the edges of which just meet.

SCHRAGE MOTOR. An electric motor of the polyphase commutator type having variable-speed shunt characteristics. See MOTOR.

SCOTT SYSTEM. A method of connecting electrical transformers to

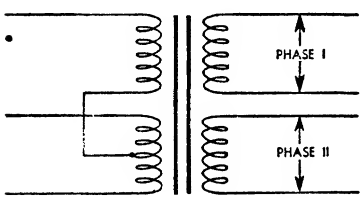
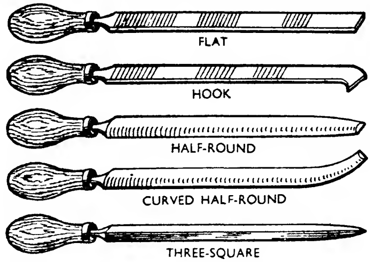


Diagram of Scott system of transformation from three-phase to two-phase.

link a two-phase system with a three-phase system. The connexions are shown in the diagram.

SCRAPER RING, see OIL-CONTROL RING.

SCRAPERS. Hand tools for the removal of metal, especially in the final preparation of machined surfaces for assembly. They are of value when hand-finishing machined surfaces which have to be fitted together. Scraping involves the removal, by a sharp cutting edge, of minute portions of metal; it has the effect of making the surfaces more close-grained and smoother than when they left the machines. It may involve the creation of an accurate flat surface, which is checked for flatness (after scraping off the high spots) against a surface plate or straight edge. The high spots are located by imparting a very thin



Examples of a hand tool for removing high spots from a machined surface.

coating of oil mixed with lampblack, Venetian red or Prussian blue; the straight edge, surface plate, or mating part, as the case may be, is then rubbed against the part to be scraped, when, on separating the surfaces again, the high spots will show up bright where contact has rubbed the marking medium away. The high spots are removed by a scraper and the marking is again applied, the process being repeated until an even distribution of contact over the area is obtained.

Scrapers, which, as illustrated, are of various forms for different surfaces, must be very hard and ground very sharp. The flat scraper is used for plane surfaces; the hook scraper for finishing or light work, or in confined spaces; half-round scrapers (straight or curved) for the curved surfaces of bearings etc. The three-square scraper is useful for relieving sharp contact points. Scrapers are often made from old files, suitably ground and tempered, but better results are obtained if special scraper steel is used.

SCREEDS. Thin strips of plaster or cement mortar, laid on surfaces to be treated with plaster or concrete, as a guide in bringing the finished work to a true level or to the slope required.

The straight-edge or screed-board is laid across these strips or ridges, and acts as a "line" to ensure that there are no bumps or hollows. Usually the screed-board is worked backwards and forwards, and up and down, until the required surface is obtained.

SCREENED-GRID VALVE. A term generally applied to a tetrode

(four-electrode) radio valve. See TETRODE.

SCREENING (Aero. Engineering), see BONDING.

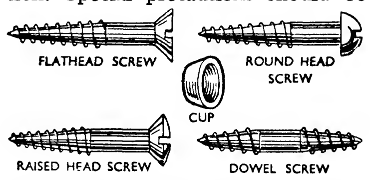
SCREENING (Radio). The electrostatic or electromagnetic separation of two electrical circuits or parts thereof. Electrostatic screening is usually accomplished by enclosing one or both circuits in a copper or aluminium container; wires may be so screened by means of a metallic braid. The container or braid, as the case may be, is connected to earth or to a common low-potential point.

Magnetic screening involves the use of a shield of high permeability magnetic material. Screening, important in radio apparatus, is chiefly used to avoid unwanted inter-action or coupling between circuits and to prevent pick-up of noises and hum due to stray fields.

SCREWDOWN (Metallurgy). The means of exerting pressure on the roll-necks in a rolling mill and thence on the roll barrels for reducing the thickness of rolled material. In the earliest forms, each screwdown was individually hand-operated, and while the basic operation has remained constant, modern systems are largely electrically controlled and operated, so that pressure may now be accurately applied while the material is actually in the rolls, and simultaneous adjustment may be made to both screws.

SCREWS. Cylindrical metal fastenings for fixing to wood, having a tapered, helical thread and a slotted head for turning with a screwdriver. Screws for use in metal have a parallel thread, and there are other variations for special purposes. Wood screws may be of iron, brass, copper, gun metal or alloys, and they may be japanned, galvanised, oxidised, nickel or chromium-plated. The head may be flat, round, or raised. The sizes vary from ¼ to 6 in., and the diameter, or gauge, varies from number 0 to number 24.

When ordering screws, both length and number must be stated, in addition to metal and finish. It is usually necessary to prepare the hole for a screw by boring with a bradawl or hand-drill, and the hole should be countersunk for a flat-head screw, especially in hard wood. A smear of grease considerably eases the insertion. Special precautions should be



Four of the more common varieties of screw for use in woodwork. Centre is shown the cup sometimes employed to protect paint on coverboards.

taken with brass screws as they break easily. For fastening down cover boards likely to require periodic removal a cup, as illustrated, is sometimes used. This allows the screw to be removed without damaging the paint work.

The following hints will be found useful for removing corroded screws: clean the head and slot, heat the head with a red hot iron, oil round the head, and then leave it for a short time. Other forms of screws are coach, dowel, grub, nail and set screws. In mass production screwing machines are used for iron screws.

SCREW THREADS. A helix machined on an external surface (usually cylindrical) to cause motion of the surface longitudinally by mating with a complimentary helix. There are several types of screw thread in use in Great Britain as well as many additional varieties in foreign practice.

The commonest British form is the Whitworth thread, which is of triangular cross-section, the angle between the sides being 55 deg. The tops and bottoms of the threads are rounded off, so as to reduce their depth by one-sixth. British Association ("B.A.") screw threads are used chiefly for small diameter work and have an angle of 47·5 deg., the depth being 3/5 of the pitch. British Standard Fine ("B.S.F.") threads are also favoured in certain applications,

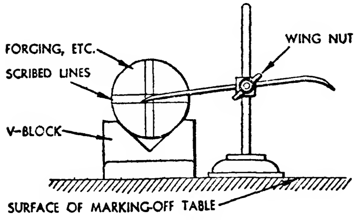
especially in parts liable to vibration or impact; they resemble the Whitworth form, but are much finer.

The normal cross-section of screw threads is the triangular or "Vee" form, but the square-section thread is used where it is desirable to keep the frictional resistance to a minimum. Other varieties of cross-section for threads for special purposes are knuckle threads and acme threads (used for lead screws of lathes, since they are so easily engaged with the slide rest), and buttress threads (used when the pressure is normally in one direction only, as in vices). The *pitch* of a screw is the distance measured axially from a point on a screw thread to the corresponding point on the next thread.

Screws are normally given one thread only, which is a helix making a definite angle with the perpendicular to the screw axis. However, two or more threads are sometimes cut (see MULTIPLE THREADS). The *lead* of a screw is the distance through which it is caused to move axially when given one turn; it is thus equal to the pitch for single threads, to twice the pitch for double threads, to three times the pitch for treble threads etc.

SCRIBING BLOCK. A device used for gauging horizontal machined surfaces, to estimate whether they are level etc. It is known in the U.S.A. as a *surface gauge.*

A scribing block consists, as shown in the illustration, of a fairly heavy



General layout and principal parts of scribing block or surface gauge.

base, usually circular and made of mild steel, the underside of which is finished perfectly flat. Into the base is screwed an upright circular rod, carrying an adjustable clamp. The clamp is split and the two portions held together by a wing nut, so that the clamp may be moved up and down the upright rod to any desired setting. Through the clamp runs a round, hardened steel wire pointed at both ends; one end is generally curved round to a fairly generous radius (say 2 in.). The steel wire passes through the clamp in such a way that it, too, is subjected to the clamping action when the wing nut is tightened.

The scribing block is often used for marking-off circular forgings etc., mounted in V-blocks which rest on the marking-off table. The centres of such objects can be found by scribing two parallel lines, the first one slightly above the centre (as estimated by eye); then the forging is turned through 180 deg. and another line scribed across the same end. The bar is then turned through 90 deg. and a similar line is scribed with the same setting of the scribing block; finally an additional half-turn of 180 deg. is given and the fourth line is scribed. The true centre can then be accurately placed between the intersections of the two pairs of lines.

SEAM WELDING, see SPOT WELDING.

SEAPLANE. An aeroplane in which the wheel undercarriage is replaced by floats so that it can operate off water. To obtain lateral stability on the water two floats of equal size are generally fitted, though there are a few seaplanes fitted with one large centre float to give the required buoyancy, and two small floats near the wing tips for stability only.

At one time it was the custom to fit a tail float to obtain longitudinal stability. Nowadays, however, the main floats are made long enough to do this.

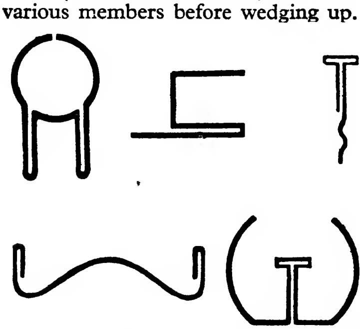
SEASONING. Reducing the moisture content of wood to proportions suitable for the purpose for which the timber is to be used. The method of doing so varies with different woods, but kiln seasoning is the most efficient and economical. It requires expert supervision for the correct

treatment to avoid checks, warp etc.; and improved methods and control, to avoid case-hardening, are constantly being introduced. The latest treatment is the application of urea.

The strength, durability and stability increase with the reduction of the moisture in the wood. Dry wood is about twice as strong as saturated wood, and 50 per cent stronger than air-seasoned wood, but the wood should be in equilibrium with its surroundings, which means that the moisture content of the wood should compare with the humidity of the atmosphere. The moisture content of felled logs varies considerably according to the species and is seldom less than 40 per cent. The following suggestions for seasoning are approximate: limit for fungoidal growth, 20 per cent; air-dried, 14 per cent; roof timbers, 14 per cent; exterior work, 16 per cent; interior joinery (ordinary heating), 12 to 14 per cent; (central heating), 8 to 10 per cent. The following formula is used to obtain the percentage moisture content:

$$\frac{\text{original weight} - \text{oven-dry wt.} \times 100}{\text{oven-dry weight}}$$

Other methods of seasoning are air-seasoning, by stacking in the open air, and water-seasoning, by immersing in running water. *Second seasoning*, or stoving, is a further drying in a warm room for interior joinery, after framing together the various members before wedging up.



Illustrated above are a few examples of sections which can be produced in mild steel or non-ferrous metal on a modern cold section rolling mill.

SEA WATER. The composition of sea-water is not quite constant; in some places the sea contains less dissolved matter than in others. The following percentage composition is believed to be a rough average:

Oxygen	85·79
Hydrogen	10·67
Chlorine	2·07
Sodium	1·14
Magnesium	0·14
Calcium	0·05
Sulphur	0·05
Potassium	0·04
Nitrogen	0·02
Bromine	0·01
Carbon	0·01
Iodine	0·006
Remainder	0·004
	100·000

Sodium chloride is obtained from the sea in several places by evaporation; magnesium and bromine are obtained from the sea in commercial quantities.

SECONDARY CELL. A reversible electrolytic cell which, after use, can be restored to its original condition electrically. Synonym: Accumulator. See LEAD-ACID ACCUMULATOR and NICKEL-IRON CELL.

SECOND-CHANNEL INTERFERENCE, see SUPERHETERODYNE RECEIVER.

SECONDARY COIL. The coil in which the high-tension impulses are generated to produce the spark at the sparking-plug points of a petrol-driven internal-combustion engine. See INDUCTION COIL.

SECONDARY EMISSION. The liberation of electrons from an object owing to bombardment by a stream of electrons or ions. Almost all metals and some insulators will emit secondary electrons. See ELECTRON MULTIPLIER and EMISSION.

SECONDARY WINDING. The winding of an electrical device, particularly a transformer, from which power is taken. See PRIMARY WINDING.

SECTION ROLLING (COLD). The cold-rolling to profile in thin gauges of non-ferrous metals and

mild-steel strip. The machine design comprises a heavy cast-iron base with a series of small rolls in sequence above. Rolling in this case is truly continuous, since the strip material may be passing through eight pairs of rolls at once. Even when a comparatively simple profile is to be imparted, it may be profitable to use the whole machine, as rolling speed may thereby be increased and material wastage avoided by means of gentle deformation. A diagrammatic view of section rolling is given in the illustration on the opposite page.

SECTION ROLLING (HOT). Sections may be produced in much the same manner as heavy hot strip is rolled, the shaping media being the rolls. The required profile is produced gradually, starting from the billet or bloom, a range of sections being readily obtainable. The rolling temperature is not critical, the main requirements being that the sequence shall be concluded before the material cools sufficiently to endanger the rolls, and that preheating shall not cause excessive scale or "burning".

SEEBECK EFFECT. Synonym for thermo-electric effect (q.v.).

SELECTIVE FADING. In radio reception, a type of distortion due to changing conditions in the ionosphere. It is particularly noticeable in regions where ground and sky waves are of about equal intensity. The varying phase relationship of these two signals gives rise to a peculiar tonal distortion of telephony transmission. See FADING (Radio) and RADIO-WAVE PROPAGATION.

SELECTIVITY. The extent of the ability of a radio receiver to distinguish between the desired signal and signals of other frequencies. Selectivity is usually expressed as the signal strength required to produce a given receiver-output at so many cycles off resonance, the response at resonance being taken as reference. See RADIO RECEIVER and TUNING.

SELENITIC CEMENT, see CEMENT.

SELENIUM (Se). Atomic no. 34; atomic wt. 78·96. There are at least two allotropic modifications of this element: one is a red amorphous solid with a density of 4·26, soluble in carbon disulphide, CS_2. The other is a grey crystalline metal, with a density of 4·8, insoluble in carbon disulphide. The melting point of selenium is from 170 deg. to 220 deg. C., and it boils at 688 deg. C. The grey metal is a conductor of electricity, and the conductivity is greater in the light than in the dark, a property which is used in photo-electric cells.

Selenium is used for colouring glass and forms a number of compounds. In its chemical properties it resembles sulphur, and is usually hexavalent or tetravalent.

SELENIUM RECTIFIER. An electrical rectifier making use of the property possessed by a processed selenium film formed on a metallic surface such as iron. Selenium rectifiers have characteristics similar to those of copper-oxide rectifiers but resistance in the forward direction is lower; thus, their efficiency and current-handling capacity for a given size are greater.

SELF-BIAS. Automatic grid bias (q.v.).

SELF-CAPACITANCE. Capacitance in a single electrical circuit, as opposed to mutual capacitance between circuits. See CAPACITANCE.

SELF-CENTRING CHUCK, see CHUCK.

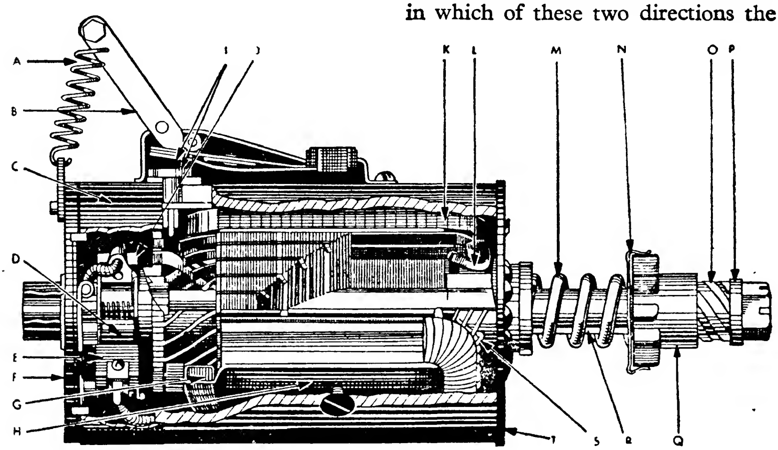
SELF-CENTRING FLOORS, see HOLLOW-TILE FLOORS.

SELF-INDUCTANCE. Inductance in a single electrical circuit, as opposed to mutual inductance between circuits. See INDUCTANCE.

SELF-STARTER. An electric motor used as a means of setting in motion an internal-combustion engine, particularly on a motor vehicle. In construction, as shown overleaf, it is similar to a dynamo, but in this case the starter converts electrical energy into mechanical power. A special type of drive is fitted which engages with teeth on the periphery of the flywheel.

The shaft of the starter motor extends beyond the casing and carries a screwed sleeve, the thread usually being of square section. This sleeve

is coupled to the shaft by means of a spring, while a loose pinion rotates on the thread. When the starter pedal or button switch is pressed, the shaft of the electric motor revolves



SELF-STARTER AS EMPLOYED IN AUTOMOBILES

Section of electric starter-motor for an internal combustion engine. Component parts are as follows: A switch plate spring, B switch lever, C commutator cover, D commutator, E carbon brush, F end plate, G field winding, H pole piece, I switch contacts, J carbon brush, K field winding, L armature winding, M buffer spring, N pinion retaining spring, O spiral spring, P stop washer, Q drive pinion, R armature shaft, S armature winding, T end plate.

rapidly and the loose pinion, by reason of its inertia, is screwed along the thread until its teeth mesh with the toothed rim of the flywheel, the spiral spring taking up the shock of transmission.

A stop is provided on the sleeve so that the loose pinion cannot slide any farther, and the motor now turns the crankshaft so that the initial firing-stroke takes place.

As soon as the engine rotates under its own power, its higher speed automatically "unwinds" the pinion so that the latter returns to rest. Thus the starter is protected from damage even should the starter switch remain depressed.

SEMI-FLOATING AXLE, see Axle.

SENSE-FINDER. In radio direction finding, an aerial employed to augment the directional reception qualities of a frame aerial. By swinging a frame aerial round, the line of a transmission can be determined.

For example, the transmitter might be known, by this means, to be either due north or due south of the frame aerial, and a sense-finder establishes in which of these two directions the transmitter in question lies.

SENSING, see Direction Finding.

SENSITIVITY (Elec. Engineering). A term used in connexion with electrical measuring instruments to indicate the deflection produced by unit change in the quantity measured, or the change in the quantity required to produce unit change in deflection; for example, μA/mm.

SENSITIVITY (Radio). The extent to which a radio receiver can respond to signals of various strengths. Sensitivity is generally expressed in terms of the number of microvolts required to be applied between aerial and earth terminals to produce a given receiver output. See Radio Receiver.

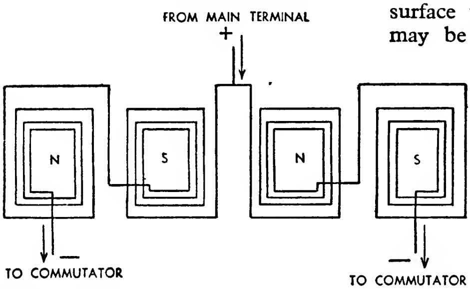
SERAYA, see Mahogany.

SERIES. A method of connecting electrical apparatus in such a way that only one path is available for the cur-

rent, which must traverse each piece of apparatus in turn. See PARALLEL.

SERIES MOTOR. An electric motor in which the field and armature are connected in series. A motor having series characteristics is one whose speed varies widely with load. See MOTOR.

SERIES-PARALLEL. A combination of series and parallel connexions in an electrical circuit. This is a common method of connecting the



Series-parallel method of connexion often used, for example, in self-starters. Letters N and S indicate the North and South poles respectively.

field coils in a self-starter motor in order to. reduce internal resistance. The diagram shows the method of connecting four field coils in two groups of two coils in series.

SERIES WINDING. A field winding of an electrical machine which is connected in series with the armature, and through which the whole of the armature current normally passes. The word series is not normally used when there is no other field winding.

SERIES-WOUND. The term applied to an electrical machine when the field coils of the motor are connected so that current flowing from battery or mains to motor would first pass through the field coils and then complete the circuit through the armature. On an automobile, the self-starter motor is the only series-wound machine. See STARTER.

SERVICE CEILING, see CEILING.

SERVO TAB, see BALANCED CONTROL.

SET-OFF (Printing). A trouble arising from the "stacking" of printed sheets, whereby the wet printing impression partly adheres to the back of the sheet on top. See ANTI-SET-OFF SPRAYER.

SEWAGE. Water containing urine and excreta, as distinct from waste or surface water; the latter may be merely rain-water from roofs or other drained areas. Sewage must be carried to the sewer by underground or enclosed systems of drainage, with proper means of ventilation, whereas surface water, as its name implies, may be carried by surface drains. See DRAINAGE.

SHADED POLE. A pole of a magnetic circuit which is wholly or partly surrounded by a metal band for the purpose of obtaining a phase difference between two fluxes. The construction may be used in an induction instrument (q.v.).

SHANKS, see LADLES AND SHANKS.

SHAPING MACHINES. Machine tools in which the workpiece is clamped to a metal table provided with traversing gear, whilst a cutting tool, clamped to a heavy "ram", moving horizontally in fixed slides, removes the unwanted metal. In practice, shaping machines are generally used for light work, heavier jobs being done on planing machines. The stroke of an average shaper rarely exceeds, say, 14 to 18 in.

Shaping can also be applied to the machining of concave or convex surfaces by the use of special appliances. The ram carries the cutting tool and can have its stroke adjusted by the setting of a connecting rod which may be clamped at any desired point on the length of a slotted crank.

The front part of the machine carries an angle plate which moves up and down on vertical slides and also carries cross-slides, these two pairs of slides enabling full adjustment of the workpiece to be made.

Since cutting takes place in one direction only, it is profitable for the return, or idling, stroke to occupy as

little time as possible in comparison with the cutting stroke; some kind of quick-return motion, usually the Whitworth type, is therefore provided. See WHITWORTH QUICK-RETURN MOTION.

SHEAR, see STRESS.

SHELLAC. A natural product, the exudation of an insect which feeds upon the sap of certain trees in India, commonly known as "lac trees".

The sap which is thus absorbed undergoes a chemical transformation during its passage through the insects, and on contact with air forms a shell-like composite crust for both the insect and the twigs upon which it feeds.

This change causes it to differ from all other vegetable resins in that it is soluble in alcohol and in an alkali water solution. It is not soluble in turpentine and will withstand the action of acids. This immunity makes it an ideal material for placing between the knots and sappy portions of timber; these contain crude turpentine, which is a solvent for linseed oil and oil paint.

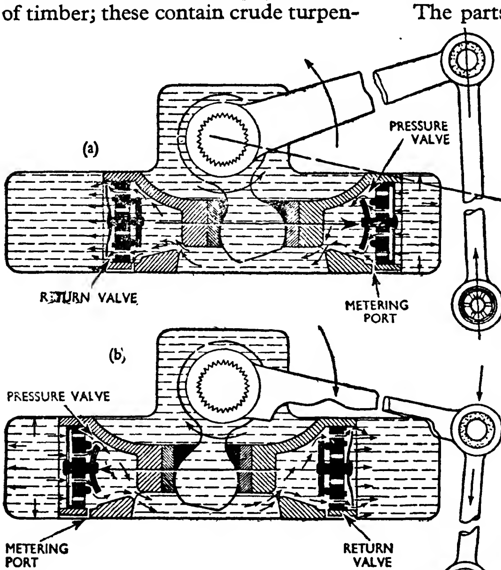
Further, the acid contained in the media of the superimposed paint cannot cause its breakdown. Shellac is used by painters mainly in the fabrication of knotting (q.v.); also for rapidly obtaining a glossy finish, termed French polishing (q.v.), and for insulating purposes in the electrical industry.

SHELL-TYPE TRANSFORMER. A type of electrical transformer in which the magnetic circuit encloses the windings, as opposed to a core-type transformer in which the reverse is the case. Shell-type transformers are well adapted to resist the deforming effect of electromagnetic forces. See TRANSFORMER.

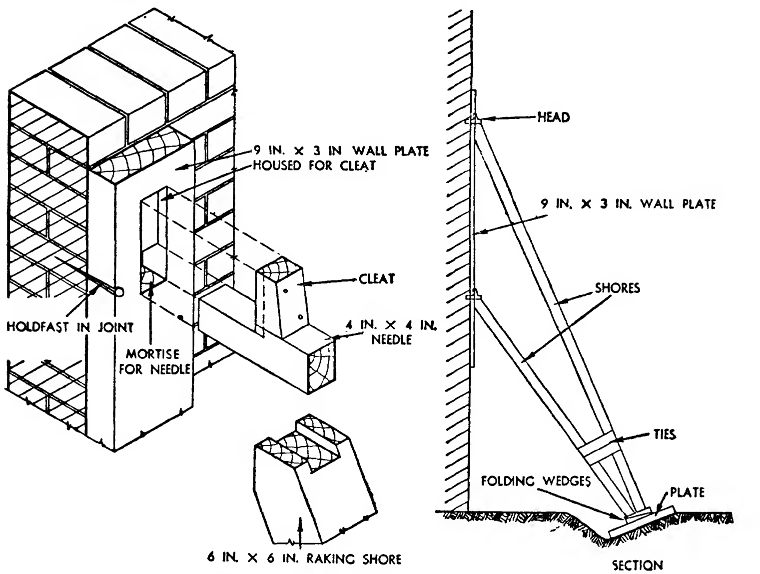
SHERARDIZING (Metallurgy). The formation of a zinc-alloy corrosion-resisting coating on iron and steel parts by cementation in zinc-dust.

The parts to be treated are packed in commercial zinc-dust in tightly closed boxes, which are then heated in a furnace at a temperature of 350 to 400 deg. C., which is below the melting-point of the zinc (419 deg. C.). The process takes about three hours, during which time a rough, greyish coating is produced on the iron parts. This consists of an alloy of iron and zinc, and contains about 90 per cent. or more of the latter metal.

The composition of the alloy layer corresponds approximately to the formula $FeZn_{10}$. The thickness of the coating is about 0·0025 in., and since it does not tend to accumulate in crevises and holes, it can be applied to articles such as bolts which are unsuitable for hot galvanizing. Corrosion-resistance of properly sherardized parts is good, but if the



Two positions of hydraulic shock absorber. Arm is shown rising (a) and right piston compressing fluid in its cylinder. Arm is descending (b) and fluid, under pressure in left-hand cylinder, is squeezing through metering port and pressure valve.



RAKING SHORE FOR WALL IN DANGER OF COLLAPSE

Details of head and correct sizes of timber for one of the three recognized types of shoring, with (right) sectional view of completed structure in position.

zinc-dust used is contaminated with iron the latter metal becomes incorporated with the coating in excessive amounts, and rusting then occurs.

SHIELDED POLE. Synonym for SHADED POLE (q.v.).

SHIELDING. Another term for screening (q.v.).

SHIM. A thin metal washer used as a means of absorbing end play in a shaft or for making fine adjustments in bearing housings etc.

SHIPPING MARKS, see TIMBER.

SHOCK ABSORBER. A device incorporated in the springing equipment of a road vehicle to damp-out shocks to the axles caused by irregularities in the road surface. Shock absorbers are now usually of the hydraulic type, an up-to-date example of which is illustrated diagrammatically, in two distinct positions, on the opposite page. This Luvax-Girling unit incorporates the principles of fluid friction and the incompressibility of liquids, fluid being forced through small holes by rotating vanes or moving pistons.

An alternative design, though one largely replaced by the aforementioned hydraulic type, consists of two arms pivoted together with friction disks inserted between them, one arm being connected to the axle and the other to the chassis at a point directly above.

In perfect suspension the road springs respond immediately to irregularities and then return slowly to their normal state; shock absorbers assist in bringing this about.

SHORING. A temporary timber structure to support walls when they are liable to collapse, and known as "raking", "flying" and "horizontal". These shores, as shown in the accompanying diagram, comprise wall pieces, needles, sole pieces, struts and cleats.

In fixing raking shores the heads of the shores are notched for the accommodation of the needles, which are passed through the wall-plate, and inserted into a space cut into the brickwork. The sole plate is placed

at right-angles to the angle of the shore, and the shore is levered into position so that its head is tight against the needle. To assist in preventing the shearing of the needle, a cleat is fitted in a mortise and situated immediately above the needle. See TEMPORARY TIMBERING.

SHORT-CIRCUIT. A low-resistance path between points in an electrical circuit, which may occur either accidentally or by design. Stray strands of wire at terminal points are a common cause of unintentional short circuit.

Earth-return circuits are very susceptible to shorts brought about by the breakdown of cable insulation, which allows the conductor to make contact with the metal parts, which are of opposite polarity. If a short-circuit occurs as a result of a conductor of very low resistance contacting two sides of a supply source, there is danger of excessive heating and subsequent fire to surrounding materials.

A safety limit can be set by inserting in the system a fuse which would melt at a high current flow, resulting in a break in the circuit.

SHORT WAVES. A term broadly applied to radio waves whose wavelength is less than 50 metres. It was once thought that these short waves had little practical value, but later investigation and experiments proved that this was not the case. See RADIO-WAVE PROPAGATION.

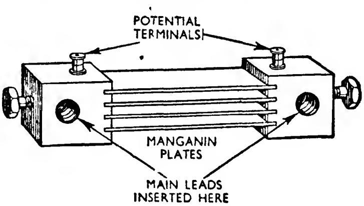
SHOT EFFECT. Noises in a radio receiver due to irregulatities in the emission of electrons from valve cathodes. It arises from the fact that cathode current, i.e. electron emission, consists of a movement of separate particles rather than a continuous fluid-like flow. See NOISE.

SHRINKAGE (Metallurgy). Solidification shrinkage is the reduction in volume that occurs when a metal changes from the liquid to the solid state. It should not be confused with solid shrinkage, or contraction, which is the reduction in dimensions produced when a metal cools to ordinary temperatures from its solidification temperature (see CONTRACTION OF CASTINGS).

Alloys with a high shrinkage are in general more difficult to cast, owing to the possibility of draws being formed. The difficulties are increased if the alloy has a short solidification range. To avoid drawing, large runners and risers will be required and these should be carefully placed to obtain the best possible feeding. In addition, chills may be employed to equalize the cooling rate throughout the casting. See CHILL and RUNNERS AND RISERS.

SHUNT. An alternative path in an electrical circuit, or a winding connected in parallel with an armature, as in a shunt motor (q.v.). This term is particularly applied to an instrument or measurement shunt which is designed to give a certain P.D. when a known current is passed through it.

By connecting a milli-voltmeter across the shunt an ammeter is made. Standard four-terminal shunts on the principle of that illustrated have current and voltage terminals which must not be interchanged.



Shunt so made that resistance is exact between the potential terminals. Fine adjustments are effected by filing one of the plates. Rods are sometimes used instead of plates.

SHUNT MOTOR. A type of electric motor in which the field winding is in parallel with the armature. A motor having a shunt characteristic is one whose speed is substantially independent of load. See MOTOR.

SHUNT WINDING. A winding in electrical equipment which is shunt, or parallel, connected. See SHUNT and SHUNT MOTOR.

SHUNT-WOUND. A term applied to electric motors and generators.

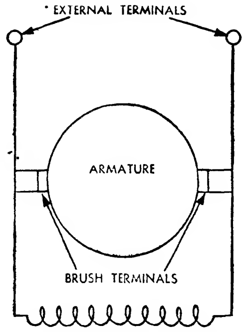


Diagram illustrating shunt-wound field windings in electric motor.

If the field windings of either of the above machines have their two extremes connected to the two main terminals of the armature the windings are said to be shunt-wound or coupled. This method of connecting the field circuit is shown above.

SHUTTERING, see FORMWORK and TEMPORARY TIMBERING.

SIDEBANDS. Beat frequencies produced when one wave is modulated by another. For example, in radio, if a 1000 Kc/s carrier wave be amplitude-modulated by a 5 Kc/s audio frequency, the resultant wave can be shown to include the following components: 1000 Kc/s (the original carrier) and two new frequencies, which are 1005 Kc/s and 995 Kc/s. Known as the upper and lower side frequencies respectively, these latter represent the sum and difference of the original frequencies of the waves mixed.

In radio telephony, the modulated wave is complex and thus instead of single side frequencies there are groups which are called sidebands.

SIDE FREQUENCIES, see SIDEBANDS.

SIDESLIP. The movement of an aeroplane in a sideways or lateral direction. The term is usually applied to inward sideslipping only, an outward sideslip being known as a skid.

A sideslip can be unintentional, as, for example, when a turn is made without the correct amount of bank; or intentional, as a manœuvre during landing in order to lose height when the approach has been made too high.

SIENNA. A natural mineral pigment containing both iron and manganese. It is a good stainer, permanent and fairly opaque in a water medium but transparent in contact with oil. In its natural form it is known as *raw* sienna and is a warm, or reddish, yellow; its colour is changed from a yellow to a rich red and its transparency improved by heating. Siennas are chiefly used as transparent washes to alter the hue and tone of an existing colour scheme and in the processes of graining (q.v.) and marbling (q.v.).

SIGNATURES (Printing). Symbols put in sequence on the first page of each book section to ensure correct order in binding. There is no standard trade practice either in the particular symbol used or in its position. It is usually placed at the bottom-right corner of the page, but may be in the centre or even on the bottom-left corner.

When the alphabet is used A is usually reserved for preliminary matter, the text beginning with B (J, V and W are often omitted). If this is insufficient the letters are duplicated AA, BB. The American method of numbering the sections is frequently followed.

Another way is to print as a signature mark about a 2-em length of 6-point rule on the outer fold of each section, in such position that the end of one is immediately followed by the beginning of the next. These equally spaced black tabs readily indicate any missing or misplaced sections.

SILENCER, see EXHAUST SILENCER.

SILICA BRICKS. Fire bricks containing more than 90 per cent of silica in the form of cristobalite and tridymite. They will stand a very high temperature.

SILICATE GRINDING WHEELS. Abrasive wheels in which the abrasive material is bonded with silicate of soda. After the abrasive and the bond have been well mixed together, they are pressed into shape in moulds; if

the wheel is very large, or if it has to be specially thin, hydraulic pressure is employed for this process.

After moulding, the wheels are placed in ovens for baking, which needs much less time and a much lower temperature than in the manufacture of vitrified wheels because, in the case of the silicate, a chemical action is set up which hardens the bond, causing it to set. This quick manufacture is one of the great advantages of silicate wheels.

Other good points are that large wheels with this bonding are safe and reliable; furthermore, the moderate baking heat does not lower the cutting powers of the abrasive material. For added safety, silicate wheels may be made on wire webbing or on iron backs. As less heat is generated in use if silicate wheels are employed, they are useful for grinding carbon-steel twist drills, where the temper at the cutting edge might be impaired, with a consequent decrease in efficiency, if too great a heat were allowed to arise.

The principal difficulties in using silicate wheels are that (1) hard and soft spots may be present unless the wheels are very carefully moulded, and (2) the cutting qualities are not so free as in vitrified wheels.

SILICATE OF SODA. A combination of silica and sodium soluble in water; generally known as *waterglass*. A weak solution extended as a film is, when dry, practically proof against re-solution with cold water; it may, therefore, be used for waterproofing external stone, brick and plaster surfaces. It is only mildly caustic and, when dry, such surfaces can be painted with oil paint.

Silicate of soda will readily make a union with grease and non-drying oils, but it has little action upon a dry oil-paint film and is in consequence a good material for washing down old and dirty paint, varnish and enamel work. A weak solution is laid upon the surface with a soft-haired brush, with no scrubbing; this is allowed to stand for a few minutes (but not long enough to become dry) and is then removed with a sponge and clean water; finally it is rewashed with clean water and leathered off.

A weak solution is also the best material to use as a lubricant in the preparation of old painted surfaces before repainting, because it has no action upon the flesh of the hands; in addition, the surface does not require neutralizing with an acid before the application of the new paint.

SILICON (Si). Atomic no. 14; atomic wt. 28·06. This non-metallic element is the second most abundant element in the crust of the earth, oxygen being the most abundant. Silicon forms 27·7 per cent of the earth's crust. Its density is about 2·39; it melts at about 1450 deg. C. It is to be found sometimes in crystalline, at others in amorphous, form; in its chemical properties it resembles carbon; it is tetravalent and forms hydrides, SiH_4, Si_2H_6 and others, a sulphide, SiS_2, silicon tetrachloride, $SiCl_4$, silicon chloroform, $SiHCl_3$, and a number of organic compounds.

The principal oxide, silica, SiO_2, is the main constituent of sandstone, flint and many other rocks. Silica exists in several varieties, one of which is quartz (q.v.); large transparent crystals of this are known as rock crystal.

Quartz readily crystallizes in hexagonal prisms with hexagonal pyramids, some of which are right-handed and others left-handed; crystals of a purple colour due to the presence of manganese are called amethysts. Opal, chert, flint and jasper are partly quartz and partly amorphous silica.

When quartz is heated above 575 deg. C. it changes into a new variety known as β-quartz. Above 870 deg. C. it is transformed into a modification, tridymite, which is transformed into cristobalite above 1470 deg. C. These changes are of importance in the use of refractory materials for lining furnaces.

Silica gel is an amorphous form of hydrated silica, which may contain as much as 90 per cent of water; it is

used to absorb benzene and other vapours from the air and for other purposes.

There are an immense number of silicates, some of which are important, among them felspars (silicates of potassium, calcium and aluminium), leucite, olivines, mica, garnets, topaz, zeolites, beryl, serpentine, talc and many others. They are mainly silicates of aluminium and sodium or of aluminium and potassium.

Glass is a fused mass of silicates of potassium, calcium, lead and sometimes other compounds. Clay is a hydrated silicate of aluminium.

Silicon ester, $Si(OC_2H_5)_4$, is a mobile, oily liquid that slowly decomposes in moist air, forming a gelatinous layer of silica; it is used for water-proofing stone or bricks. "Waterglass" is a sodium silicate of the approximate composition $Na_2Si_5O_9$, used for preserving eggs. Silicon carbide, SiC, otherwise known as carborundum (q.v.) is an important abrasive. See also QUARTZ and ZEOLITES.

SILICON BRONZE. An alloy of copper and silicon, containing 3 to 5 per cent of silicon with small amounts of manganese, iron and zinc. If the amount of zinc is large the alloy is more correctly termed silicon brass, although a number of such proprietary alloys still retain the name bronze.

Silicon, like tin, is a hardening agent but is about two and a half times more effective. A silicon bronze containing 4 per cent silicon is therefore equivalent to a 10 per cent tin bronze. These alloys are considerably stronger than gunmetal, but are more difficult to cast.

Silicon bronze now forms the subject of a British Standard Specification, B.S.1030:1942. Requirements are as follows: Silicon 1·50 to 5·00 per cent, manganese 1·50 per cent max., zinc 5 per cent, iron 2·5 per cent max. and other elements 0·5 per cent max. A tensile strength of 20 tons per sq. in. with 15 per cent elongation is required.

SILICON STEEL. A low-metalloid steel alloyed with proportions of silicon varying from 0·2 to 4·5 per cent, and used for the laminated magnetic circuit of electrical apparatus of all types.

Silicon steel was first made by Hadfield when trying to develop ferrous alloys, in the late 1880s, for structural purposes. It was found that these alloys had advantageous magnetic properties, and a report of the joint work of Barrett, Brown and Hadfield, published in 1900, showed that 2½ per cent silicon steel has twice the maximum permeability, 25 per cent lower hysteresis, and four times the resistivity of the normal soft-iron sheets used for this purpose at that period.

The importance of this increased resistivity was not noticed by the publisher of the paper, but Gumlich drew attention to the vital nature of this particular property in its effect on the eddy-current loss with A.C. magnetization. The soft-iron cores used at that time had a total loss of 3·50 watts per kilo at B.10,000, 50 cycles.

By 1903, sheets of the new iron-silicon alloy were being produced commercially. The modern low-loss transformer sheet with 4·0 per cent silicon, 0·014 in. thick, is available with a total loss of 1·0 watts per kilo at B.10,000, 50 cycles.

The effect on iron of the silicon addition is as follows: silicon is soluble in iron up to 15 per cent and lowers the conductivity of the iron; for example, soft-iron has a resistivity of 10 microhms per c.c., whereas a 4 per cent silicon-iron alloy has a resistivity of 55 microhms per c.c.

The second major effect of the silicon is to precipitate the carbon as graphite, in which form it has much less effect on the magnetic properties of the iron.

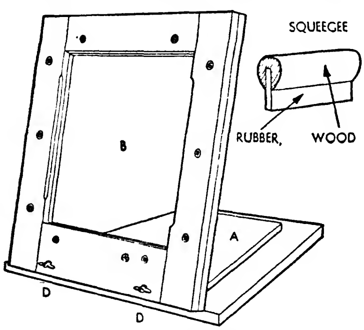
Lastly, silicon has a very great affinity for oxygen, and rids the iron of the bulk of oxygen in solution, which has almost as deleterious an effect on the magnetic properties as carbon in solution.

SILK-SCREEN PROCESS. A printing process used for the production of small quantities of prints, say

from 20 to 1000. Any flat material such as paper, card, metal, plywood or laminated wood, glass, leather, rubber, or textile fabrics, can be printed with equal facility. Window displays and showcards are typical productions.

The paints selected are usually opaque, and they dry with a matt finish. A range of glossy inks is also available, as are translucent inks, which are particularly effective on glass tablets.

Normally no machinery is used and equipment is very simple, the main item consisting of a hinged frame, shown in the diagram. The base holds



Simple form of silk screen; an effective means of printing on flat surfaces in a variety of materials.

the sheet of material to be printed, and provision is made for register. A sheet of specially woven silk, stretched across the open top section of the frame (B), acts as a support for the stencil. Various stencils are used according to the type of work. A thin hard paper, or greaseproof, serves where the subject is bold, while metal foil also has its uses. For greater detail a double-skinned film is used; the top skin cuts away readily and cleanly to form the stencil, while the lower layer supports the stencil until it is transferred to the underside of the silk screen (B).

For detailed work, the screen may be covered with a light-sensitive film which is exposed to arc lamps through a photographic positive. The parts which are not thus hardened wash away during the development and form the open parts to the stencil, while the hardened film prevents the passage of paint through the screen. Printing is simple; the sheets are placed on the base (A), and the frame closed on the hinges (D).

Paint is poured on one end of the silk (B) and propelled by a rubber squeegee (F) to the opposite end of the screen. Paint thus penetrates the silk locally through the stencil and prints the sheet, which is immediately removed. The operation is repeated as many times as required.

The bulk of work is in the nature of cut-outs, showcards etc. Two probable ways of development are (a) increased speed through mechanical control (b) artistic application for limited quantities, e.g. book covers, book end-papers and the like.

SILL. The member forming the base of a window opening. Its function is to throw off the rainwater and to form a covering to the wall at the base of the opening.

A drip should be formed by cutting a groove in the projecting undersurface and an inclined top surface, or weathering, should also be provided. Sills are usually longer than the window openings, the ends being built into the walls. When a hardwood sill surmounts a stone sill, a groove for a metal water-bar should be provided in the detail.

SILVALITH. A modern method of preparing lithographic printing plates by sensitizing the metal plate with photographic emulsion in place of the normal colloidal solution. The metal plate is then placed in the dark slide of the camera, and the photographic negative or positive is fixed in the transparency holder. The exposure is a matter of seconds.

Normally a positive printing image is obtained from a positive photographic image; but either a transposed, or a deep-etched, image may readily be obtained by alternative processing.

SILVER (Ag). Atomic no. 47; atomic wt. 107·88. A white, malleable metal with a density of 10·49, which melts at 960·5 deg. C. and boils at

1955 deg. C. It occurs in many lead ores, from which it may be obtained by cupellation and in other ways. Silver is monovalent, forming silver chloride, AgCl, silver bromide, AgBr, silver iodide, AgI, and silver nitrate, $AgNO_3$. The last, also known as lunar caustic, is used as a caustic for warts, and in solution as a disinfectant.

SINE WAVE. A sequence of values of any quantity, but particularly of electrical quantities, such that the relation between the value of the quantity and time or position is the same as the relation between an angle and its sine. See ALTERNATING CURRENT.

SINGLE-ACTION PRESSES. A type of press with one ram; the simplest model is the fly-press shown in the illustration, where the rotary motion, by hand, of heavy iron balls at the top of a screw causes the vertical traverse of the ram carrying the punch. Power-operated single-action open-fronted presses are usually driven from a flywheel which contains a friction clutch operated by a foot pedal.

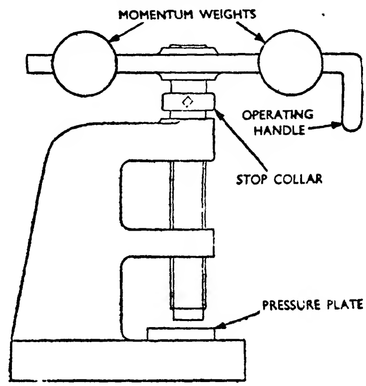
The ram is reciprocated vertically by a crankshaft, but the clutch is automatically disengaged just before the ram reaches the top of the stroke, in which position it is held by a brake. The brake is effective only when the foot pedal is released, so that the press can be kept running continually for blanking from strip stock.

Open-fronted presses are generally made inclinable so that pressings fall by gravity, and are suitable for light blanking, not usually over 50 tons pressure, and for raising, forming or bending.

Double-sided presses are used for heavy blanking and general presswork, and may be 80 in. or more between the standards, with tonnages up to 500 tons and beyond. Smaller sizes have solid frames, while larger machines are of built-up construction.

Horn presses or side-wheel presses are used for grooving side seams, but when fitted with an adjustable table are suitable for light punching and raising on large sheet-work for which clearance on the press front is required.

Direct-drive presses are used generally for work in which the pressure is required over a small fraction of the working stroke, as in blanking or piercing, but if the effort is required over a large section of the stroke, then geared presses are preferable. For sections of large dimensions, as used in the automobile industry, fabricated steel-frame presses of 2000 tons capacity and 20 ft.



Fly-press, a simple form of single-action press. Momentum weights in this model are rotated by hand, thus causing the vertical ram to move up and down over the pressure plate.

between standards are in use, while forging presses up to 6000 tons capacity are made. Pressure is applied by toggle levers and eccentric shaft motion. See COINING PRESS, DOUBLE-ACTION PRESS AND HYDRAULIC PRESS.

SINGLE-CUT FILE, see FILE.

SINGLE FLOOR. A floor which spans a compartment without intermediate support. Such floors are generally suited to domestic buildings; larger buildings create larger spans, which require the introduction of one or more floor beams, thus dividing the floor area into two or more bays.

SINGLE-PHASE. An electrical circuit or piece of equipment in which there is one A.C. voltage, as opposed

to polyphase (q.v.), in which there are two or more.

SINGLE-PLATE CLUTCH, see CLUTCH.

SINGLE TUP, see EARING.

SINK. A sanitary appliance for the discharge of waste water after washing etc., usually of glazed stoneware or earthenware. Teak and lead-covered wooden sinks can be used where glassware has to be washed. Stainless steel and monel metal have in some cases replaced the glazed type.

SIPHONIC ACTION. Action set up in an inverted-U tube, having one leg longer than the other, when the shorter length is placed in a tank of liquid, which liquid is caused to flow over the crown of the tube and down the longer leg.

Steps must be taken to get the liquid in motion, but, once started, siphonic action will continue until the level in the tank has been reduced to the bottom of the short length of the inverted U. The weight of liquid in the longer leg is greater than that in the shorter; consequently, the longer overbalances the shorter, and suction causes the flow to continue.

To empty a cistern or tank by means of siphonic action, immerse a length of hose pipe in the tank so that the pipe becomes filled with liquid, stop-up one end with a cork, pull this end over the side of the tank until it is lower than the tank bottom, and withdraw the cork.

SITE CONCRETE, see SURFACE CONCRETE.

SIZE. The name given to several materials used in painting when in ready-for-use condition. Water-soluble size is, in general practice, made from glue, although isinglass (q.v.) and gelatin have a limited use. Glue size is used as a priming coat upon plastered surfaces which are to be finished with ordinary distemper or hung with paper; it is also incorporated in ordinary distemper to bind together its solid contents and to form the means of attachment to the surface to which it is applied.

It is not suitable as a first coating upon plaster surfaces which have to be painted, or upon timber surfaces to be painted, stained or varnished, because it prevents adequate penetration of the surface by the oil medium. This type of size is used in glass gilding (q.v.) as a means of attachment and may be used upon metalled surfaces as a protective film.

An oil size known as japanners' gold-size (q.v.) is a material prepared in the same manner as an oil varnish; it is used as a binding medium in paints made from pigments ground in turpentine, and also as a fixing agent for gold and other metallic leaves and bronzes. Diluted with turpentine or white spirit, oil sizes are used for correcting the absorptive qualities of timber in preparation for varnishing.

SKID (Aero. Engineering), see SIDE-SLIP.

SKIN EFFECT. An electrical phenomenon which causes the alternating-current density in the outer layers of a conductor to be greater than that of the inner layers. It is not usually of importance at low frequencies, but at high frequencies the effect is very marked and causes an appreciable increase in resistance.

SKIN FRICTION. Friction which has the effect of retarding the progress of an aeroplane through the air. The air in contact with any part of the exterior surface of an aeroplane in motion through it is at rest, while, at a short distance from the surface, the full velocity of the air-stream is reached.

The layers of air are thus sliding over each other, either smoothly as in laminar flow (q.v.), or in small eddies as in turbulent flow. Friction is thus set up, the retarding force being known as skin-friction drag.

SKIN-PASS MILL. In metallurgical work a set of rolls, either two-high or four-high, through which the sheet is given a light pass in order to impart the desired surface finish, to produce a slightly hardened surface, or to give a shape that will roller-level flat.

There is little difference in the mill design from that of the two- or four-high units for ordinary rolling,

except that the design need not be quite so robust, since thickness reduction is not the primary requirement.

SKIP DISTANCE. In radio communication, the length of the skip zone (q.v.). See also RADIO-WAVE PROPAGATION.

SKIP ZONE. In radio communication, the area between the terminations of the useful ground wave and the commencement of ionospheric wave reception. The extent of such a zone depends upon transmission frequency and the state of the ionosphere. See RADIO-WAVE PROPAGATION.

SKIRTING. The finishing at the junction of the wall and the floor. Wood, cement plaster or metal may be used. Wood skirtings are fixed to plugs or timber grounds and form a plinth to the wall surface.

The bottom edges of skirtings of this kind are often tongued into the floor to allow for contraction, otherwise an open joint would soon become apparent. A fillet or quarter-bead may be nailed to the floor, thus closing the angle joint between the floor and the skirting.

For many years it has been common practice to use timber skirtings, but in modern construction metal skirtings, known as "metal trim", are frequently used.

SKY WAVE. A radio wave which reaches a receiver after having been reflected by the ionosphere. See RADIO-WAVE PROPAGATION.

SLAB FURNACE. A furnace in which, after rolling to thickness in the blooming mill in continuous rolling, and being end-trimmed and cut to size, the slabs are brought to rolling temperature before being sent on to the roughing and hot-finishing trains.

Slabs are propelled through the furnace on water-cooled skids, evenly heated on all sides, and ejected singly to a roller conveyor.

At the discharge end of this type of furnace there is incorporated a soaking zone in which the black spots are soaked out. The heat is automatically equalized to rolling temperature by the aid of recording pyrometers (q.v.).

SLAG. A vitreous mass sometimes consisting mainly of aluminium silicates that separate from metals during the smelting of the ores. Basic slag contains much calcium phosphate and free lime; it is produced in the manufacture of steel by the basic-hearth process. The phosphate in it makes it a valuable fertilizer.

SLAT (Aero. Engineering), see SLOT.

SLATING. The process of forming an efficient roof covering with a number of pieces of slate cut to special size. Slates are named according to their sizes as:

(1) Duchess 24 in. long by 12 in. wide;
(2) Countess 20 in. long by 10 in. wide;
(3) Ladies 16 in. long by 8 in. wide.

Slates should not be used on a roof surface having an angle of inclination less than 26 deg. to the horizontal. They may be fixed to battens nailed direct to the roof rafters, or the roof may be close-boarded and battened.

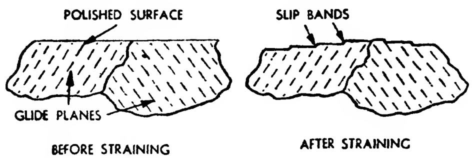
The terms connected with slating are: *Lap:* the distance by which each slate overlaps the next but one below it. The distance may be taken as 3 in. *Margin:* the part of each slate which is exposed on the roof surface; and *Gauge:* the distance from centre to centre, between the battens.

SLEEPER WALL. A low wall, built under the ground floor of buildings which have no basement, to provide an intermediate support for the floor joists, thus reducing the span and economizing in timber.

Walls of 4½-in. bricks are built up from the surface concrete, and timber wall-plates are bedded on top of the sleeper walls. To prevent dampness rising to the timber, the wall-plate should be placed immediately above a damp-proof layer of bituminous felt or slates.

Ventilation under the floor is obtained by leaving spaces in the brickwork at intervals throughout the length of the wall. The wall is then said to be "honeycombed".

SLIDE REST. The movable portion, in a lathe, which carries the tool post



Cross-section of two crystals much magnified, showing method of formation of slip bands.

or holder. The slide rest is a slotted table mounted on a "saddle", and may be designed for automatic or self-acting turning, or for screwcutting.

The saddle bears on the two V edges of the lathe-bed, and also comprises two slides capable of traversing along V-shaped edges, one being arranged for surfacing, and the other for sliding. A hand-operated screw governs each of the resulting movements, which take place in directions mutually at right-angles.

For turning tapered surfaces a circular swivelling adjustment is also incorporated. The slide rest, in addition to its control by the hand-operated screws, may also be worked by power through the rack and pinion, or through the lead screw, according to the type of work involved. See Capstan Lathe and Lathe.

SLIDING FITS (Mech. Engineering), see Running and Sliding Fits.

SLIP (Elec. Engineering). The extent to which the actual speed of an electric induction motor differs from its synchronous speed (q.v.). It may be expressed in r.p.m., or as a fraction or percentage of the synchronous speed. Slip is normally of the order of 5 to 10 per cent at full load and very small on no load.

SLIP BANDS. Marks appearing on the polished surface of metal under stress. If a piece of metal is stressed, while being examined under the microscope, a number of parallel dark lines appear on the bright surface as soon as the metal receives a small amount of permanent deformation. The number of lines multiplies rapidly as the deformation increases.

As the process continues, a second or even a third set of lines may appear on each crystal at an angle to those formed initially. Slip bands, as they are called, do not form on all the crystals in the metal at once. Crystals possess definite directional properties, deformation accruing by a process of gliding on parallel planes.

Each crystal may possess several sets of planes along which slip is relatively easy, so that those crystals most suitably arranged with regard to the applied stresses will be the first to show slip. The accompanying illustration shows a cross-section through a strained specimen containing two crystals differently oriented.

SLIP-RING. A ring-shaped rotating conductor in an electrical machine, which, together with a brush (q.v.), enables current to be transferred from a fixed circuit to a moving circuit or vice versa.

SLIPSTREAM. The wake behind an aircraft propeller. The air in the slipstream, having been accelerated backward and given a rotational velocity in passing through the propeller disk, is flowing faster over the aeroplane than the remainder of the air. The parts of the aeroplane in the slipstream thus have a higher drag than if they were out of it.

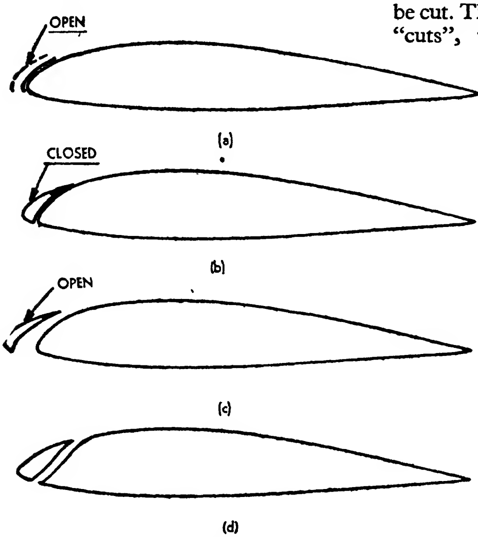
SLOGGER, see Gib.

SLOT (Aero. Engineering). The leading edge slot on the wing of an aeroplane is a device used to increase the maximum lift of a wing, by delaying the breakdown of airflow which occurs at the stall, so allowing the wing to operate at a larger angle of attack. It is also used to prevent wing-dropping at the stall by ensuring that the wing tips shall not stall first.

There are several kinds of slot, one of which is formed by a curved plate called a *slat*, fitted round the nose of the aerofoil as shown at (a) in the illustration and extending over all, or part, of the span. The slat is fitted with slides, so that under the action of the air forces at high angles of attack it moves forward and opens a

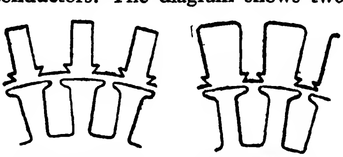
slot. Alternatively, the slat may be thickened-up as shown in (b) and (c) until it resembles a small aerofoil. These two kinds of slot were originated by Sir F. Handley-Page.

Sometimes permanently open slots are used as shown in (d), but as fitting them leads to an increase in drag under normal operating conditions their use is generally restricted to the prevention of wing dropping, since only short lengths near the wing tips need be fitted for this purpose.



Slats and slots. At high angles of attack slat on leading edge slides forward to open a slot. Diagram shows some different shapes of slat.

SLOT (Elec. Engineering). An axial groove or tunnel in or near the rotor or stator surface of an electrical machine, which is designed to contain conductors. The diagram shows two possible forms of slot in section. See LAMINATION.

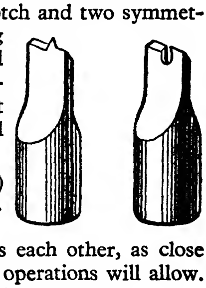


Slots cut into edges of laminations to accommodate conductors leave metal projections called teeth, shown above.

SLOT CUTTING. The machining of slots or key-ways in shafts and other components. Special forms of drill may be used; if these are correctly ground, even quite shallow slots can be cut. The method is to take roughing "cuts", with a flat-ended drill of the type shown on the left in the illustration, which will produce a flat-bottomed slot except for the additional groove caused by the drill centre. The latter is, however, necessary in the first place to correct the setting of the drill on the axial centre-line of the slot.

Having taken the roughing cuts, a special slotting drill, as shown in the right-hand portion, is substituted for the flat-ended drill, when one or two finishing cuts are taken. This drill rotates at a comparatively high speed, the workpiece being fed along horizontally at a moderate rate.

The latter cuts ensure a flat surface for the slot or key-way as the drill has no "centre"; instead there is a small central notch and two symmetrical cutting edges, ground straight and arranged so that they are carried inwards towards each other, as close as the grinding operations will allow.



Flat-ended (left) and slotting drill.

SLOT SCREW, see JOINTS.

SLUG. That mass in which a force of one pound will produce an acceleration of one foot per second. Thus the gravitational force acting on one slug is 32·2 pounds.

By dimensional theory all physical entities such as acceleration, density etc., can be defined in terms of three

fundamentals. These are generally taken as length (L), mass (M) and time (T), thus force is represented by $\frac{ML}{T_2}$. In the English system the unit of length is the foot, of mass the pound and of time the second (in the c.g.s. system they are the centimetre, gram and second, respectively).

Unfortunately, by common usage, when we talk about one pound weight we generally mean the force of gravity acting on one pound mass, which is 32·2 poundals (in London).

Arising out of this consideration was the proposal by Professor Perry, some years ago, to use force in place of mass as one of the three fundamental entities, and its unit the pound. Mass then becomes a derived entity with its unit the slug.

The unit of density used in aerodynamics is slugs per cubic ft. The density of air under standard conditions (15 deg. C. and 29·92 in. of mercury) is thus quoted as 0·00238 slugs per cubic foot.

SMALL TOOL. A tool used by plasterers for making-up mitres and

Common form of "small tool," a steel implement employed by plasterers.

intersections and for truing-up castings. It is made of steel and is of varying shapes, a typical one being shown in the illustration.

SMALT, see COBALT.

SMOOTHING. The process of filtering-out the A.C. component from the pulsating direct-current output of a rectifier used on A.C. supply mains.

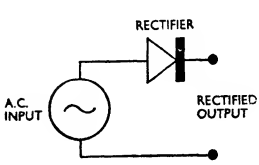
The filter itself makes use of the energy-storage properties of capacitance and inductance; the energy stored when the voltage and current are rising is given back when they fall, thus smoothing out the "gaps" in the rectified output. A theoretical diagram of the output of a rectifier is shown in Fig. 1. This pulsating unidirectional voltage can be considered as an alternating voltage, called the ripple, superimposed on a steady direct voltage.

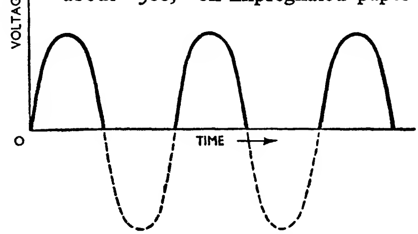
A condenser placed in parallel with such a source will short-circuit the A.C. component, and an inductance connected in series will offer a high impedance to the ripple, while not interfering with the D.C. Most filters, therefore, consist essentially of a combination of inductance and capacitance.

Practical smoothing systems are designated *condenser-input* and *choke-input*, depending upon whether a capacitance or inductance is used as the first element of the filter.

Resistance is sometimes used in place of inductance where current requirements are low and the voltage drop in the resistor can be tolerated.

For radio receivers and small amplifiers, condensers are generally of the electrolytic type, while for apparatus requiring voltages above about 500, oil-impregnated paper-

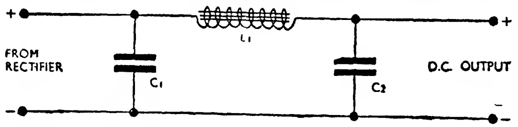




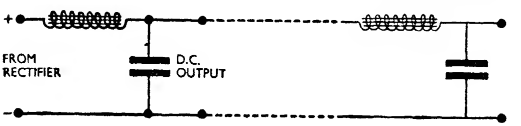
HALF-WAVE RECTIFIER WITHOUT SMOOTHING

Fig. 1. Above is shown, on the left, the connexions of a half-wave rectifier and on the right a graph of the form taken by the output without smoothing.

dielectric condensers are usual. Chokes are wound on iron cores and should have low D.C. resistance. Fig. 2 shows a single-section condenser input filter. The values of components will depend upon frequency, load



Diagrams of the two types of filter. Fig. 2, above, shows the condenser-input type and Fig. 3, below, a single-section choke-input filter.



current, and tolerable ripple content; but, for most radio receivers, C_1 and C_2 can be about 8 μF and L_1 from 10 to 20 henrys for a full-wave rectifier operating on mains having a frequency of 50 cycles per second. These values should be approximately doubled for half-wave working.

The D.C. output from such a filter will, at light loads, approach the peak transformer voltage, which is approximately 1·4 times the R.M.S. voltage of the H.T. secondary in half-wave systems, or 1·4 times the voltage from centre-tap to one end of the secondary in the case of full-wave rectifiers.

At other and heavier loads, it will decrease by an amount depending upon the current drawn, thus the voltage regulation of such a system is inherently poor. It is applicable only when the *average* current requirement is constant, and is usually employed in conjunction with metal rectifiers or hard valves.

A single-section choke input filter is shown in Fig. 3. Such an arrangement, with proper choice of circuit values, has better regulation than the condenser-input type, but as ripple content may be higher, a second section, shown right of dotted connexions, is sometimes added. The calculation of component sizes is somewhat complex and typical values cannot be quoted. Care, however, should be taken to prevent resonance effects. To take full advantage of the system, a full-wave rectifier must be used, mercury-vapour diodes being particularly suitable. The output for all except very light and very heavy loads will be approximately the average of the H.T. secondary voltage between centre-tap and one end, corresponding to about nine-tenths of the R.M.S. value.

SOAKER. A piece of lead, or other suitable material, bent at right-angles to rest against a wall immediately above a roof surface and under the tail of each slate or tile, abutting against the wall, in every course.

The function of a soaker is to make the joint between the roofing material and the wall watertight. The length is equal to the length of the gauge plus the lap, plus 1 in. The width of a soaker should be 4 in. to lie on the slates and 3 in. for the upstand, or that part which is against the wall.

SOCKET CHISEL, see CHISEL.

SODA. Sodium carbonate, or washing soda, diluted with water is the cleansing agent used in the preparation of old painted surfaces before repainting. Having a destructive action upon grease and fats, these are, by its action, easily removed by washing. It is also mildly active upon dry oil films, therefore, this property must be neutralized, by coating with vinegar all surfaces upon which it has been used.

Sodium hydroxide, or caustic soda, in solution with water, is strongly alkaline and must be handled with care. This may be used as a paint remover; all surfaces upon which it has been used must, after washing-off with clean water, be neutralized with a weak acid in solution.

SODIUM (Na). Atomic no. 11; atomic wt. 22·997. A soft, silvery

metal that combines rapidly with water. Density 0·972; m.p. 97·62 deg. C.; b.p. 877·5 deg. C. It is monovalent, chemically resembling lithium and potassium. It is prepared by the electrolysis of sodium hydroxide or sodium chloride.

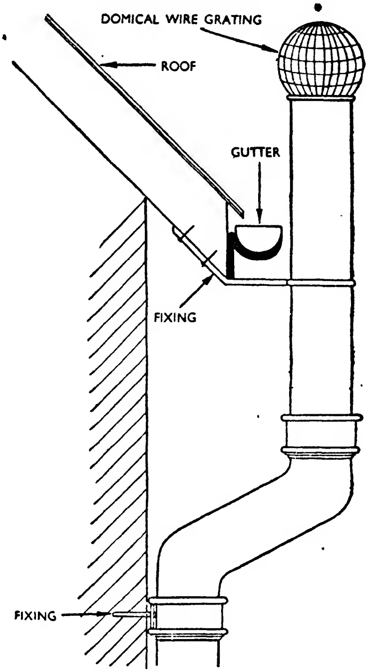
Sodium monoxide, Na_2O, unites rapidly with water, forming sodium hydroxide, NaOH (caustic soda). Sodium chloride, NaCl (common salt), occurs naturally as rock salt, and is contained in sea water to the extent of about 3 per cent. Sodium carbonate forms several hydrates, of which the decahydrate, $Na_2CO_3.10H_2O$ (washing soda), is universally known. Sodium bicarbonate, $NaHCO_3$, is very largely used in medicine as an antacid and as a lotion. Sodium chlorate, $NaClO_3$, is largely used as a weed-killer. Sodium hypochlorite, NaOCl, dissolved in water is used as an antiseptic.

When neutralized with boric acid the solution is known as Dakin's solution, and is largely used for the dressing of wounds. Sodium nitrate, $NaNO_3$, forms great deposits in S. America and is known as Chile saltpetre. It is an important fertilizer. Sodium phosphates, a sodium potassium tartrate, and sodium salicylate, are used in medicine.

Sodium sulphate, $Na_2SO_4.10H_2O$ (Glauber's salt), is largely used as an aperient. Sodium thiosulphate, $Na_2S_2O_3$, is well known to photographers under the name of "hypo". Soda ash is a sodium carbonate obtained by calcining sodium bicarbonate. Sodium compounds introduced into a flame give a bright yellow light, and the spectrum of sodium contains two bright-yellow lines with wavelengths of 5896·15 and 5890·15Å, forming the Fraunhofer lines D_1 and D_2 in the solar spectrum. Sodium is one of the few elements that are not mixtures of isotopes.

SODIUM-VAPOUR LAMP. An electric discharge lamp (q.v.) which contains sodium vapour.

SOIL PIPE. A continuation above the ground of a drain, inside or outside of a building, to which sanitary appliances such as water closets, urinals and slop sinks are connected. The soil pipe must be continued up vertically above the highest branch or junction, undiminished in diameter, to such a height and position above the eaves of the roof or above any adjacent window that the gases likely to emanate from the pipe will not be a nuisance, or cause injury to health; this part of the soil pipe, above the highest discharge, is known as the soil-ventilating pipe.



Upper portion of soil pipe, showing method of fixing and its position relative to the roof and gutter.

The illustration shows the upper termination of a soil pipe. The domical wire grating, for the prevention of any obstruction being blown into the pipe, should have apertures of such area that their sum is not less than the sectional area of the pipe. Usually, soil pipes are from $3\frac{1}{2}$ to 4 in. in diameter, and are made of

lead, cast iron, copper or asbestos. A system may have the soil pipe of cast iron, with the branch pipes of lead. Lead and copper have the advantage of a smooth bore, with strength on the side of copper; cast-iron pipes are strong, but rather rough internally from the casting. They should be galvanized or coated with bitumastic material.

Soil pipes should terminate just below ground level and be connected to the drain through a right-angle bend without a trap. This arrangement will allow the air to pass from the drain to the soil pipe, thus permitting the whole of the drainage system to be ventilated. The diameters of soil pipes are usually determined by local building by-laws.

SOIL-VENTILATING PIPE, see SOIL PIPE.

SOLDERING. Joining two pieces of metal by melting a metal alloy known as solder so that it flows over and adheres to the two surfaces. Solders can be either soft or hard. Soft solders are mainly a combination of tin and lead, with the addition of a very small percentage of antimony.

Solder containing from 2 to 3 per cent antimony is used in general work, and in tinsmiths' and coppersmiths' fine work; that containing from 1 to 2 per cent is used in plumbers' wiped joints to lead pipes; while the lower percentages are used in general electrical work, machine soldering, zinc and galvanized ironwork etc.

The term soft solder implies a low melting point, the object being to produce an alloy which melts at a temperature lower than that of the parts to be joined. The more tin in the alloy, the lower the melting point; thus, fine solder, with the low melting point of 180 deg. C., contains tin and lead roughly in the proportions 60 to 40, while plumbers' solder, with a melting point of 225 deg. C., has the proportions 30 to 70. The term hard solder is more often applied to the silver solders and spelters used in brazing (q.v.); hard solders composed of copper and zinc which melt at a high temperature, usually red heat, are employed in joining copper and its alloys.

A flux (q.v.) is necessary, chiefly to prevent the parts to be soldered from oxidizing on contact with the air, but also to help the molten solder to run freely. Varieties of flux can be obtained which are either acid or non-acid, the choice depending on whether the work can be successfully cleaned after application, to remove all traces of a corrosive nature.

Briefly, the method of soldering is as follows: the parts to be soldered are first thoroughly cleaned, by filing, scraping or rubbing with emery cloth; the flux is then applied in either paste or liquid form; next, the parts are warmed by means of the soldering iron or a flame, and the molten solder brought into contact with them. This process is known as *tinning* (q.v.); that is, laying a coat of solder on the parts so that when they are lapped and reheated the solder runs together and forms a solid joint. Fresh solder can be applied with the soldering iron

PLASTIC PERIODS OF SOLDER

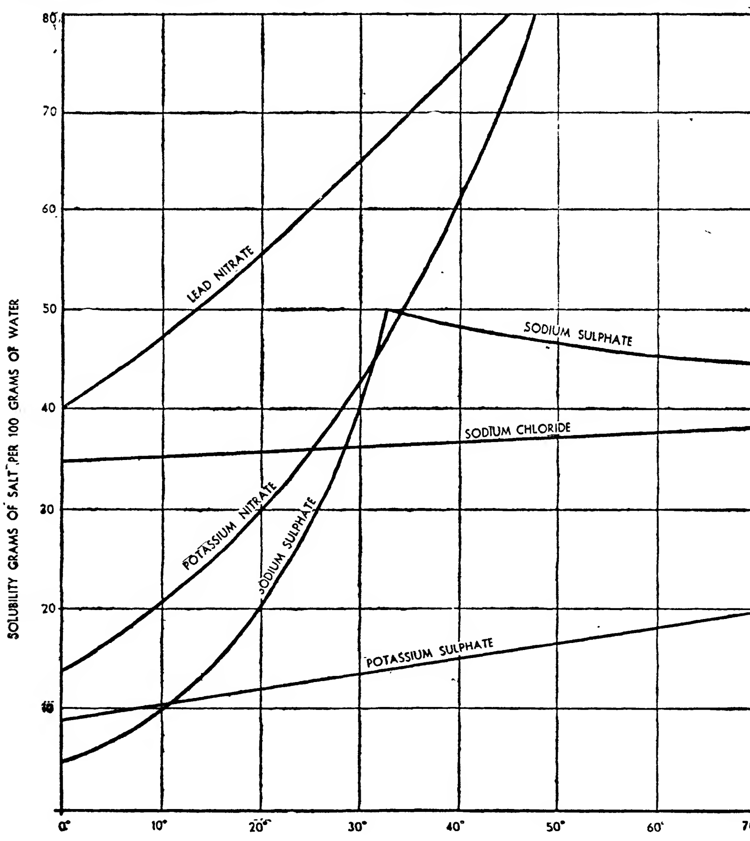
	Composition					
	Pure tin	63 per cent tin, 37 per cent lead	50 per cent tin, 50 per cent lead	40 per cent tin, 60 per cent lead	30 per cent tin, 70 per cent lead	Pure lead
	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.
Temperature when completely liquid	450	359	414	460	496	620
Temperature when completely solid	450	359	359	359	359	620
Plastic range	0	0	55	101	137	0

along the joint if this is considered necessary.

It is important that the parts should be warmed before the hot metal touches them, otherwise the sudden cooling of the solder on contact will make it useless; it will not adhere, and will break up in small pieces. Conversely, if the parts are too hot, the solder will break up into liquid drops like water on a greasy surface. Judging the exact temperature during the process requires experience.

A plumber's wiped-soldered joint to lead piping, or to brass sleeves and thimbles used in connecting lead to some other material, is made as described above save that the joint is "wiped" with a fustian cloth to form and smooth the metal. The molten solder can be either poured or splashed on to the joint, and caught with the cloth during the process. See Pipe Jointing and Fixing.

SOLENOID. A coil of wire wound in the form of a helix. Its purpose is to produce a magnetic field whenever a current of electricity is passed through the wire. The term is usually restricted to coils in tube form without an iron core, though there is often a movable iron plunger. The automatic cut-out traffic signals, dipping-headlamp reflectors and, in



Above is shown graphically the extent to which raising the temperature of water increases solubility of common salts. The sodium sulphate curve should be noted.

certain cases, self-starter switches are all solenoid-operated.

SOLID SOLUTION. A homogeneous solid containing at least two metals, the composition of which may be varied, within limits, without any abrupt change of properties.

SOLIDUS. A line in an equilibrium diagram (q.v.). It indicates the temperature at which any particular alloy becomes completely solid, or at which melting begins. See EQUILIBRIUM DIAGRAM and LIQUIDUS.

SOLUBILITY. The extent to which one metal can dissolve in another. In the liquid state most metals are completely soluble in each other; but in the solid state solubility is generally limited and may vary considerably with temperature. See EQUILIBRIUM DIAGRAM.

SOLUTION. A term used to denote (1) the process of dissolving one substance in another, and (2) the substance in which another is dissolved.

The amount of a salt that can be dissolved in water depends on the temperature, and most such compounds are more soluble in hot water than in cold; the diagram opposite gives typical solubility curves, showing the maximum amount of the solid that will dissolve at different temperatures.

The curve of sodium sulphate shows an abrupt change at the temperature of 32·4 deg. C., the reason being that at that temperature the structure of the crystals changes. Below that temperature the crystals have the composition $Na_2SO_4.10H_2O$; above that temperature the crystals are anhydrous, Na_2SO_4.

When a solid dissolves in water or any other liquid the freezing point of the solution is lower than that of the pure liquid; this depression of the freezing-point is proportional to the weight of the substance dissolved, and the molecular proportions of different substances usually produce the same depression. The boiling-point of a solution is usually higher than the boiling-point of the pure liquid, and the elevation of the boiling-point is in proportion to the weight of the substance dissolved.

When a gas is dissolved in a liquid, the higher the temperature the less is the amount of gas dissolved. Certain alloys, ordinary glass, and some other very intimate mixtures are sometimes called solid solutions; they differ from true solutions because the movement of the different particles is very restricted or negligible.

SOLVENT (Chemistry). A substance that will dissolve another substance, which is called a solute. The term solvent is mainly used to describe a liquid in which solids can be dissolved. Water is a solvent for many metallic salts; thus all metallic nitrates are soluble in water. It also dissolves a number of the sugars and other organic substances.

Benzene, acetone, alcohol, toluene, amylacetate and xylene are well-known solvents for gums, waxes, resins and plastics.

SOLVENTS (Painting). Volatile liquids obtained by distillation from materials of vegetable origin; their use may be for the dilution of oil or the solution of solids such as resins, cellulose and oxidized or dry paint films. Turpentine, used mainly as a diluent, differs from most in that it thickens on exposure through oxidation. It will dissolve a dry oil film only when heated and acts as a stimulant to paint and varnish in drying.

White spirit, a distillate from mineral oil, is used for the dilution of oil; it completely evaporates. Benzene (a distillate from coal tar) or solvent naphtha (obtained from shale) are used for materials not soluble in turpentine or white spirit.

Alcohol (spirits of wine), obtained by the distillation of fermented liquors containing sugar or starch, is used for the solution of shellac (q.v.). Other types of alcohol (hydrocarbons) are obtained by the destructive distillation of organic matter, their reactions with organic and inorganic acids forming compounds which are used for making solutions with cellulose and hard resins; they are

also the active agents in many paint removers.

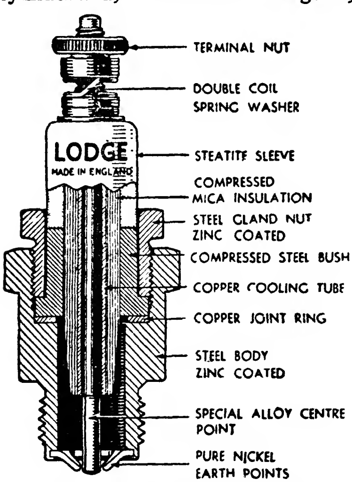
SORBITE. Finely dispersed carbide of iron in α iron formed either by the quenching of austenite or by tempering martensite. In the first case the structure will be finely lamellar, sometimes known as sorbitic pearlite; in the second case, finely granular. In steel, this structure is associated with good strength and great toughness.

SPACE CHARGE. In a radio valve a negative electric charge due to the cloud of electrons in the space surrounding the heated cathode. See RADIO VALVE.

SPAN. In an aeroplane, the distance from wing tip to wing tip, or its overall width.

SPAR (Aero. Engineering), see WING.

SPARKING PLUG. A device for introducing the spark into the combustion chamber of a petrol-engine cylinder. It is screwed into the cylinder and, as shown in the diagram,



Famous make of sparking plug fitted as standard on many petrol engines.

carries electrodes across which the spark jumps. One or more electrodes are fixed around the lower end of the plug-body which is screwed into the cylinder.

To ensure a gas-tight joint, the plug-body is shouldered to grip a copper washer between it and the cylinder as it is screwed down. The body of the plug also supports a thick insulator, made of porcelain, mica, or other insulating material, through which runs the central electrode. To the top of this electrode, which is threaded, the high-tension lead is secured by a terminal nut.

The plug centre is secured to the body by a gland nut and here again a gas-tight joint is ensured by the insertion of a copper washer between the body and the insulator. When in position the centre electrode is adjacent to the fixed electrodes of the plug-body, there being a clearance of approximately 0·018 in. to 0·020 in.

To maintain a sparking plug in good order it must be kept clean inside and out. Carbon forms on its inner surfaces and, if allowed to remain, causes internal short-circuit and misfiring. The electrodes are subjected to erosion, so that the gaps between them become excessive.

Re-adjustment of their correct setting is accomplished by bending the side electrodes towards the centre until it is just possible to place a feeler gauge (q.v.) between them. The centre should be inspected for cracks or leakage and if defective the whole plug should be replaced.

SPECIFICATION (Building). Description of all materials and workmanship required to complete the erection and finishings of a building. A specification forms the basis upon which an estimate for the cost of the work can be obtained, and should clearly define what is wanted, so that a builder is able to price the work by estimating the probable cost of material and labour from the details supplied. See BILL OF QUANTITIES.

SPECIFIC GRAVITY. The weight of a given volume of a substance relative to that of an equal volume of water. Thus if the specific gravity of the electrolyte of a lead-acid cell is 1·250 it means that it is one and a quarter times the weight of an equal volume of water.

SPECIFIC HEAT. The number of calories required to raise the tem-

perature of 1 gram of a substance by 1 deg. C. If the substance is a gas, it must be stated whether the gas is kept at constant pressure or at constant volume.

SPECIFIC INDUCTIVE CAPACITY. Synonym for permittivity (q.v.). See also DIELECTRIC CONSTANT.

SPECIFIC RELUCTANCE. Synonym for reluctivity (q.v.).

SPECIFIC RESISTANCE. Synonym for resistivity (q.v.).

SPECTROSCOPY. The art or science of studying various phenomena of light by means of a spectroscope, of which the essential feature is a transparent prism or set of prisms, or a grating.

The light from the sun or a lamp consists of vibrations of many different wavelengths, and if such light passes through a prism some of the rays are deflected more than others, and the different colours of the light are spread out in a spectrum with the red at one end, the yellow and green in the middle, and the blue and violet at the other end; the violet rays are deflected more than the red rays. There are also infra-red rays and ultra-violet rays that are invisible to the eye, and therefore outside the spectrum.

The wavelengths of light of different colours are measured in Ångström units, denoted by Å, each of which is one hundred-thousandth of a centimetre; the various wavelengths used in spectroscopy are roughly as follows:—

Ultra-violet ..	130 to 3900 Å
Violet	3900 „ 4220 Å
Blue	4220 „ 4920 Å
Green	4920 „ 5350 Å
Yellow	5350 „ 5860 Å
Orange	5860 „ 6470 Å
Red	6470 „ 7700 Å
Infra-red ..	More than 7700 Å

When a chemical element is heated until it is incandescent, it gives out light waves of a few, or many, different wavelengths, depending on the particular element; thus, hydrogen emits light of 6563 Å in the red part of the spectrum, of 4861 Å in the blue-green, of 4340 Å in the blue, and 4101 Å in the violet. Sodium emits principally light of 5896 Å and 5890 Å in the yellow-orange region.

Each element has its own distinctive spectrum, some consisting of a few lines, some of many lines. An incandescent element emits its own spectrum lines, and if a light of many different wavelengths, such as sunlight, is passed through a vapour containing a few elements, each element will absorb the rays of its own spectrum, and when viewed through a spectroscope the spectrum will be crossed by a number of dark lines, each of which belongs to, and is evidence of, some particular element.

Sunlight passes through the hot vapours surrounding the sun as well as the earth's atmosphere, and the solar spectrum contains very many dark lines proving that the hot vapours of the sun contain hydrogen, helium, sodium, potassium, calcium, iron and several other elements on the earth. See SPECTRUM ANALYSIS.

SPECTRUM ANALYSIS. As every element has a spectrum (q.v.) of several lines, each of which is distinctive of that special element, it is possible, by heating an alloy or compound until it is incandescent and viewing it through a spectroscope and noting the various lines, to identify all the elements present.

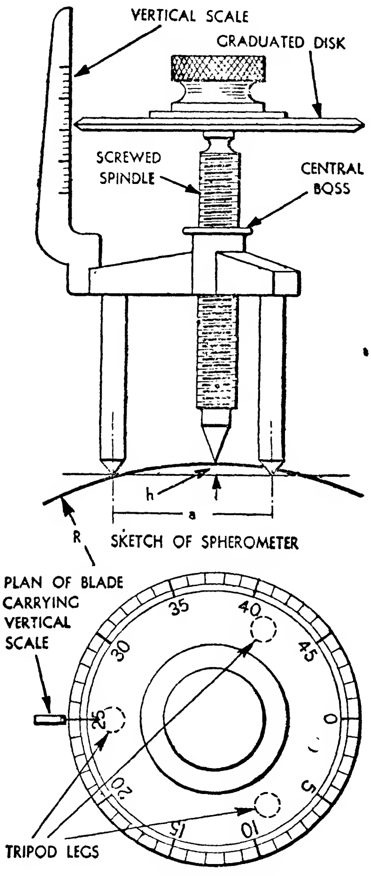
Strong lines indicate that the element is present in considerable quantity, faint lines that it is present in small quantity. By taking a photograph of the spectrum by means of a spectrograph, it is possible to determine with a fair degree of accuracy the proportion of the elements present. This method is used to find the amount of sulphur, silicon and other elements present in steel, and for similar purposes.

SPEECH COIL. Also known as voice coil. In a moving-coil loudspeaker, a coil attached to the diaphragm and free to move in the annular gap in the magnet system. Currents corresponding to speech or music are passed through the coil, which causes the diaphragm to move in such a manner as to set up sound

waves and thus to reproduce the signal audibly.

SPEED-POWER COEFFICIENT, See PROPELLER COEFFICIENT.

SPHEROMETER. An instrument which affords the most convenient way of ascertaining the radius of curvature of spherical surfaces (e.g.



Elevation and, below it, plan of spherometer, for measuring the radius of curvature of a sphere.

mirrors etc.), whether convex or concave.

It consists, as shown in the illustration, of a small tripod, the three equidistant legs branching from a central boss through which passes a threaded vertical spindle, at the top of which a small disk is fixed, graduated around its circumference.

Attached to one of the tripod legs is a vertical scale, the divisions on which correspond to the pitch of the screw on the spindle. One complete rotation of the graduated disk thus corresponds to a movement of the spindle through a distance equal to the pitch on the screw—i.e. through one division on the fixed vertical scale—which also serves as a "zero" point for readings on the disk.

To measure the radius of curvature of a spherical body, the instrument is first calibrated to obtain the "zero" reading by placing it on a glass plate and noting the scale readings. It is then placed on the spherical surface and the severed spindle adjusted so as just to touch the curved surface, without producing any rocking in the instrument. The readings of the disk and scale are again noted, and the difference between them and the "zero" readings will give the vertical height h of the segment of the sphere contained within the three feet of the spherometer. (A similar procedure is used for concave surfaces). Then if a is the distance between any two legs of the spherometer, the radius of curvature R is given by $R=\frac{a^2}{6h}+\frac{h}{2}$.

The second term, $\frac{h}{2}$, becomes negligibly small when spherical surfaces of larger radius are measured, so that R is then practically equal to $\frac{a^2}{6h}$.

SPIGOT. A spigot joint is one where a piece of metal is recessed to form a close-fitting collar around another piece of metal. The end of a shaft, hollowed out to receive a bearing supporting a second shaft so that the two rotate in alignment, is termed a spigot bearing. This type of bearing is used in the gearboxes of motor vehicles where the primary or driven shaft supports one end of the main shaft.

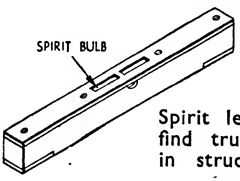
SPIN. Flight of an aeroplane in a continuous spiral descent in a stalled

condition. It is found from tests with models in a wind tunnel that an aeroplane wing in an unstalled condition is stable in roll, but once the stalling incidence has been exceeded, it will continue to rotate. This motion is called auto-rotation.

Consider now what happens when an aeroplane stalls. It will go into a steep, straight dive and as it gains speed will become unstalled. Should it suffer a disturbance causing it to start a roll, and if this is uncorrected, or if there is not enough control to prevent it, auto-rotation will set in and the aeroplane will descend in a spiral path, still in a stalled condition, and is said to be in a spin.

Recovery from a spin is made by centralizing the controls, and then pushing the control stick forward to unstall the aeroplane, which then goes into a steep dive from which it may be pulled out in the normal manner. The danger in a spin lies in the height that is needed for recovery.

SPIRIT LEVEL. An instrument used for obtaining a true level. It usually consists of a glass tube, set in the top edge of a suitable piece of wood, as illustrated. The tube is filled almost to capacity with a coloured spirit or non-freezing mixture. The air bubble left in the tube moves towards that end of the tube which is raised above the true level. A brass strip with a slot in it is usually screwed over the tube, both



Spirit level used to find true horizontal in structural work.

the protection and to act as a scale; when the bubble is cut exactly in the centre by the line of the brass strip, the instrument is reading dead level.

Spirit levels used by bricklayers and carpenters often have a circular hole cut in the middle of the wood upon which they are mounted to allow another level to be set at right-angles to the edges. This enables true vertical readings to be taken. Levels for other purposes are made of metal, some precision instruments having dials graduated in degrees.

SPIRITS OF WINE, see ALCOHOL.

SPLINESHAFT. A *spline* is a special form of key, involving several similar grooves on the shaft instead of the single groove required by the ordinary key. Splines are used when

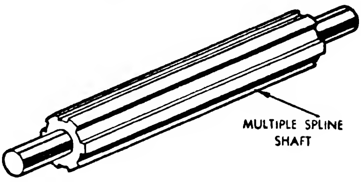


Illustration shows how keys form integral part of milled splineshaft.

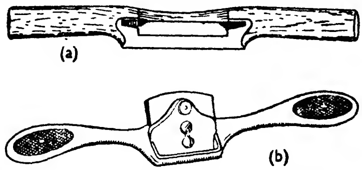
it is necessary to allow a hub to slide axially along a shaft, while constrained at the same time to rotate with it.

If small, the splines may be fixed into the shaft by dovetailing, or they may be fixed in position by countersunk screws. Normally, however, splineshafts are produced by milling, as illustrated, so that the protruding keys are left integral with the shaft, to engage with corresponding grooves in the internal bore of the hub. The grooves make it impossible for the hub to rotate relatively to the shaft.

The splines themselves may have either straight parallel sides, or may be of the involute pattern, generated by a hob provided with teeth like the basic rack of involute gears.

SPLIT-PHASE. A term applied to electrical apparatus in which currents having a considerable phase-difference are produced from a single-phase supply. It is particularly used to describe a type of single-phase motor which is rendered self-starting by the use of two windings and a phase-splitting circuit. See MOTOR.

SPOKESHAVE. A small two-handed plane as illustrated, for shaping curved woodwork. The narrow blade of a wooden spokeshave (a) is fixed by two tapered prongs that wedge tightly into the



Illustrated above are examples of (a) wooden and (b) metal spokeshave.

wood stock. The metal type (b) has a larger blade and is more easily adjusted.

SPONTANEOUS COMBUSTION. Ignition without the application of a flame. Most fuels will ignite in combination with oxygen provided the temperature be high enough. Thus, petrol will burst into flame in oxygen at a temperature of 270 deg. C.; coal gas will burn spontaneously in air at 850 deg. C.

Spontaneous combustion (pre-ignition) is one of the factors which limit the compression ratio that can be used in the ordinary internal-combustion engine, that is, of the electrical- or spark-ignition type.

SPOT WELDING. The process of joining two similar or dissimilar metals together at one point, or at a succession of separate points. It may be carried out by any one of three methods: gas welding, arc welding, or resistance welding.

The most common form of gas welding employs the oxy-acetylene flame, which is used to heat the parts to be welded, the weld being made by feeding-in metal from a rod. This rod, or filler metal, melts as the weld proceeds and unites with the metals to be joined, forming a welded whole; the metal is then allowed to cool. This process lends itself to seam welding, and while spot welding can be carried out, the term is accurate only in the sense that the length of the seam is very short. *Seam* welding denotes the joining of two similar or dissimilar metals at a succession of points so close to one another that they overlap and constitute a continuous-seam weld.

The process of arc welding (q.v.) consists of raising the parent metals to a welding heat by creating a high-temperature electric arc close to them. This is done by passing a current of several hundred amperes between the parent metals and a movable electrode, the latter being a filler rod of suitable metal.

Current-flow is started by bringing the rod into contact with the work; the arc is then formed by drawing the rod electrode a short distance away from the work. The arc heats up the parent metals and the electrode rod, the latter being consumed as it is transferred in molten form to the parent metal, with which it unites. The weld is then formed and the metal cools as the arc moves further along the seam. This process lends itself to seam welding, but spot, or "tack", welds can be made by using seam welds of short length. Arc welding is particularly useful in welding fabricated parts of great size, which would present great difficulty in handling, even if they could be joined by the resistance-welding process.

In resistance welding, which is the best-known process, "spot" and "seam" are more clearly differentiated. In both cases the parent metals are heated to a welding temperature by passing a heavy current of several thousands of amperes through a section of the parent metals. The electrical resistance of the section of the parent metals opposes the flow of the current, and as a result the metals are raised to a high temperature. At the same time the metals are subjected to heavy mechanical pressure which forces them together, causing them to unite and become welded.

Unlike gas and arc welding, this process does not involve the feeding of extra metal into the weld. Hence it has the merit of economy.

In spot welding, the two pieces of metal to be welded are pressed together by two "electrodes" in the form of copper-alloy rods of some 1 or $1\frac{1}{2}$ in. diameter, the tips of which, in contact with the parent metals, are of a much-reduced diameter; the

actual diameter at the tip may be of the order of $\frac{3}{16}$ or $\frac{1}{4}$ in.

This has the effect of confining the welding current to a narrow section of the work. The current is switched on, the work heats-up, and when the correct temperature is reached the current is switched off; the pressure between the electrodes forges the metals together and consolidates the weld. The electrode pressure is then removed and the work released.

On some machines the electrodes are made to reciprocate up and down in quick succession; this enables a number of spot welds to be made, close to one another, the work being fed through slightly by hand when each separate spot is completed. This is known as continuous-spot welding; it enables articles to be welded-up quickly, and allows spot welds to be made in awkward positions inaccessible to the disk or wheel electrodes of a seam welder, which, for example, cannot weld around sharp radii etc.

The weld resulting from the continuous-spot welding process cannot be considered gas- or water-tight, as the spacing of the individual spots depends on the skill of the operator in feeding the material through the electrodes. But for a large number of applications it provides a quick method of welding-up articles which need not be watertight, and it can be carried out on an all-purpose spot welder. That is, a continuous-spot welder is usually arranged to make single spots when desired.

In seam welding, the electrodes take the form of copper-alloy disks, between which the work is placed and, as in the spot welder, subjected to heavy mechanical pressure. The disk electrodes are caused to revolve, and at the same time the current is turned on and off intermittently. When the current is switched on, a single-spot weld is made as the electrodes rotate, and during the subsequent current-off period this spot weld is consolidated under pressure.

When the current is switched on again, a second spot weld is made, partially overlapping the first. This cycle of operations is repeated, and in this way a gas-tight seam weld is produced. It is usually considered that at least ten spot welds are required per inch run to obtain a gas-tight seam.

When welding is carried out at a linear speed of 10 ft. per min., it will be seen that some 1200 welds will be made each minute. This means that the current has to be switched on and off some 1200 times per minute, and as no contactor can do this, ignition control is now being widely used. The mechanical pressure is removed at the end of the seam, the electrodes separate, and the work can then be removed.

SPRAYING PROCESSES, see Metallic Coating.

SPRAY PAINTING. A method of mechanical painting in which liquid preservation and decorative materials such as paint, varnish, lacquer etc., are projected by means of compressed air. The material used is thinned-down with a volatile diluent which forms no part of the dry film.

The pneumatic tool, or appliance, used is known as the "spray-gun". The requisite operational air is obtained by using an air compressor, of which there are two types, reciprocating and rotary. This can be driven by electric motor, petrol or paraffin engine, or from existing shafting. Where a reciprocating compressor is used, it is necessary to pass the air through a vessel known as an air receiver, which has the effect of storing the air, thereby blanketing-out the pulsations and ensuring a steady stream of air.

Air under pressure will condense, and it is therefore necessary to pass it through a purifying medium before delivery to the spray-gun. The air supply, carried to the spray-gun by a flexible rubber hose, passes through the gun and finally emerges through a nozzle or air cap.

The supply of paint to the spray-gun may be effected by various means, viz. gravity feed from a cup attached to the gun or from an overhead

container, suction feed from an underslung cup, or pressure feed from a vessel linked to the gun by a flexible hose. In each case the paint is finally expelled through the spray-gun nozzle from a small central conical jet. The fluid flow is permitted by the withdrawal of a needle machined to fit the interior of the jet and controlled by a trigger action as shown in the accompanying illustration.

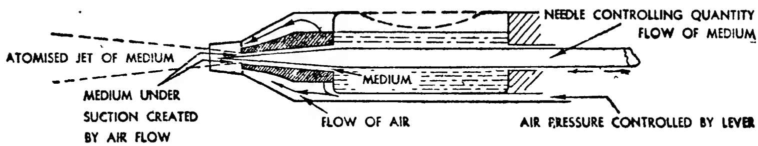
The air emerges from the nozzle through a hole which surrounds the fluid jet, and its motion on escaping atomizes the fluid into minute globules which are carried in the airstream on to the object being sprayed, where they flow into each other, forming a perfectly smooth film or coat. The form taken by the spray fan in this case is perfectly round.

By introducing auxiliary air-escape holes in the nozzle in juxtaposition to the central air and fluid outlets so as to impinge at a certain angle, the round spray form is made to flatten and spread, giving an increase in the width of the paint coverage.

Comprehensive research by manufacturers has determined the exact relationship of the air pressure, size, angle and positions of the various air and paint orifices so as to require the minimum volume of air at as low a pressure as is consistently possible with the maximum speed of application.

For large work, there is a considerable saving in the time taken for application of the paint, but for small and intricate work this advantage is offset by the time occupied in the application and removal of a masking tape specially prepared for that purpose. Regulations are also imposed as to the wearing of masks and special clothing to protect the operator.

Spray painting has completely displaced hand-brushing methods in most phases of paint work in the sheet-metal industry, and, moreover, has enabled paint to be applied to surfaces hitherto considered inaccessible. The enormous saving of time and superior appearance of the finished article has also ensured the permanency of the process.



SPRAY-GUN FOR APPLYING PAINT OR VARNISH

Pneumatic tool by means of which a film of material may be added to various surfaces for preservative or decorative purposes, or for a combination of both.

SPRIG. A cheap form of nail made by a stamping process from sheet-iron or steel. Sprigs are used for reinforcing the faces of moulds or cores, where necessary, to prevent scabbing, erosion of the mould faces, and the breaking away of parts of the cope.

The sprigs are pushed into the faces of green-sand moulds so that the heads are about $\frac{1}{32}$ in. below the surface. In this way, when the sand contracts under the action of the hot metal, a smooth surface is obtained. If this precaution is not observed the heads of the sprigs will leave impressions on the casting.

In dry-sand moulds the sprigs need only be pushed in level with the mould face, since such moulds are more resistant, and in any case the sprigs will be covered with a layer of blacking. For this purpose sprigs about 2 in. long are used, but longer ones are required for parts such as edges or corners, which are liable to break away from the mould. Nails with large heads may be used to protect surfaces on which a stream of metal impinges directly.

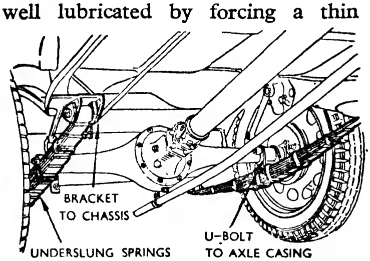
SPRING BIAS. A spring, or simple form of trimming gear, attached to any of the three control surfaces of an aeroplane to hold them in position,

thus relieving the pilot of the necessity of applying a constant force to the controls to ensure straight and level flight. The tension of the spring may be varied for different purposes.

SPRINGING. The springs on a motor vehicle support the chassis on the axles as shown in the diagram, and absorb the shocks caused by road irregularities. The commonest types of spring on modern vehicles of orthodox design are of the semi-elliptic and quarter-elliptic varieties.

The springs are built up of a number of leaves of flat steel, the top, or master, leaf having its ends rolled over to form an eye. One end of the spring is pivoted to the frame on a hardened steel pin passing through a bracket shaped to receive the spring. The other end is also secured to a bracket on the frame through a swivel link termed a shackle. The shackle allows for the varying distance between the two eye centres as the spring is flexed.

The spring is secured to the axle by two U-bolts which clamp it to the spring-seat on the axle. In certain cases the springs fit under the axle—a variation of design termed underslung springing. To maintain springs in good condition they should be well lubricated by forcing a thin



Underside view of part of chassis showing rear springs and connexions.

chisel between the leaves and applying a graphite grease.

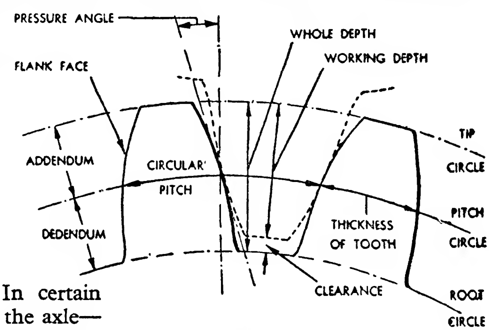
SPRING TAB (Aero. Engineering), see TAB.

SPRING WASHER. A device used to prevent a nut or set screw working loose. The washer is fitted under the nut and, as the nut is screwed down, the washer forces it on to the sides of the thread and holds it secure.

SPROCKET (Building). A piece of timber nailed to the feet of each pair of roof rafters to lower and break the pitch of the roof. Sprockets are used to produce a curve in the lower portion of a pitched-roof surface, and to ensure a close-fitting joint between the tail of the slates and those in the course immediately below.

SPRUCE, see FIR and TIMBER.

SPUR GEAR. A gear in which the teeth are cast or machined on the cylindrical surface of the blank, each tooth lying parallel to the axis of rotation of the gear. The smaller of



Details of spur gear teeth in mesh are here shown in diagrammatic form.

two such gear-wheels in mesh is called the *pinion* and the larger the *wheel*. The ratio of the number of teeth on the wheel to that on the pinion gives the *gear ratio*.

A special case is that of the pinion engaging with a rack, in which the latter is equivalent to a pitch circle of infinite diameter. For two spur gears in mesh the pitch circles can be regarded as the end elevations of the two corresponding pitch cylinders, i.e. cylinders, rotating about the same centre lines as the pinion and wheel, which would roll together with the same speed of revolution, no slip taking place.

The radial distance from the pitch circle to the tip of a tooth is called the *addendum*; the radial distance from

the pitch circle to the root of the tooth ("root circle") is known as the *dedendum*.

Circular pitch is defined as the distance, measured along the pitch circle, between two corresponding points on the flanks of adjacent teeth. The pressure angle is the angle between the tangent to the tooth profile at the point where the latter cuts the pitch circle, and a radius drawn from the wheel centre through that point. The principal details of spur gears are shown overleaf.

SQUARE. An instrument, made either of steel, wood or plastic material, or a combination of these, used for obtaining a true right-angle. It is made in different shapes for various purposes.

The draughtsman's square, known as a set square, is usually a flat triangle of some plastic substance, having one angle a right-angle and the others either half a right-angle (45 deg.) or 60 and 30 deg. The adjustable square has a movable hypotenuse, or side opposite the right-angle, with a protractor graduated in degrees.

All these are used in conjunction with the T-square, which is simply a straight-edge having a cross-piece set at right-angles at one end.

Steel squares, known as stock squares, are used by bricklayers and masons, whilst the carpenter's square has a thick, wooden stock with the square edge, lined with a brass strip, which acts as a stop against the edge of the plank or board, similar to the T-square.

SQUARE-LAW CONDENSER. In radio circuits, a variable condenser whose capacitance varies as the square of the amount by which its spindle is rotated. For example, if rotating the spindle from 0 deg. to 45 deg. changed the capacitance from 0 to 10 micro-microfarads, then a rotation of twice the amount, i.e. from 0 deg. to 90 deg. would change the capacitance by four times, namely from 0 to 40 micro-microfarads.

SQUARE-LAW DEMODULATOR. A radio-valve demodulator in which the relation between carrier voltage and the corresponding change in anode voltage obeys a square law. Most valve demodulators, other than diodes, have this characteristic which causes distortion if the received carrier is deeply modulated.

SQUARE-RIGGED AILERON, see AILERON.

SQUIRREL-CAGE MOTOR. A type of electric induction motor, widely used in industry, in which the rotor winding is closed upon itself and takes the general form of a squirrel-cage treadmill. See MOTOR.

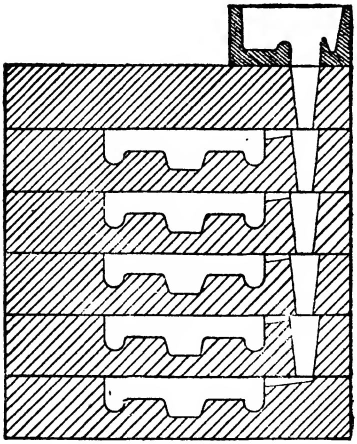
STABILITY (Aero. Engineering), see LATERAL STABILITY and LONGITUDINAL STABILITY.

STABILITY (Radio). The ability of radio apparatus to retain constant characteristics. Generally, the term refers to ability to remain tuned, not to exhibit a tendency towards unwanted self-oscillation and to remain free from drift or random changes.

STACK CUTTING. An economical method of producing blanks for simple pressing or drop-stamping operations, utilizing a suitable type of metal bandsaw. While somewhat limited depth of throat in such machines makes the method applicable only to smaller blank sizes, it is useful for short runs, and saves wasteful use of a nibbler.

The procedure is to mark or scribe the top sheet or use a metal template, clamp the stack tightly, and follow the usual metal-sawing technique. With care there should be little or no burr, and even for subsequent hand forming. dimensions can be sufficiently accurate if the pattern has been properly developed. See METAL ROUTING.

STACK MOULDING. A method of moulding, used in foundry work, in which the moulds, including runners, are made entirely in core boxes. The moulds are stacked in a vertical pile, each mould forming the cope for the mould immediately beneath it. The runners in each case connect-up to form one long runner with an ingate to each mould. The method is cheaper than ordinary methods of moulding for some classes of work, but cannot compete with



Stack moulding with continuous runner and separate ingate to each mould.

machine moulding. See RUNNERS and RISERS.

STAGE GAIN. In voltage amplifiers, stage gain is defined as the ratio of A.C. output voltage to A.C. input voltage applied to the grid. For single-stage valve amplifiers with a resistive load, it is given by the formula $A=\frac{\mu R}{R+r_a}$ where μ is the amplification factor, r_a is anode A.C. resistance and R is the load resistance in ohms.

In amplifiers with choke loads, the gain becomes $\frac{\mu X}{\sqrt{X^2+r_a^2}}$, where X is the reactance of the choke. When a transformer is used in the anode circuit, the formula is $A=\frac{\mu X_p}{\sqrt{X_p^2+r_a^2}}\times N$, where Xp is the reactance of the transformer primary and N its turns ratio.

STAIN. Discoloration or marks caused by contact with foreign matter. In painting and decorating, all surfaces to which paperhangings (q.v.) are to be applied must be free from oil and grease, as the success of the finished work will largely depend upon its clean appearance.

When paper is to be varnished an impenetrable film must first be established by applying two coatings of jellied glue size (q.v.). Pitch, tar, creosote and similar materials all impart a stain to oil paint and must be kept away from surfaces which are to receive paint. Stains may develop through painting unseasoned timber, the cause being the action of crude sap upon the applied paint; timber containing small check or sap marks should receive two coats of thin shellac (q.v.) before priming.

A stain may also be due to the growth of fungoids within the timber; these also find the nourishment they require in the oil of the applied paint. Some of the seed or spore cases of these become pigmented if the paint contains certain metals, and cause coloured patches within and upon the surface of applied paint, varnish or enamel. The suspected portion of timber, together with the surrounding plasterwork, is coated with a solution of naphthalene as a preventative measure.

STAINING. The application of a transparent, coloured wash to bare timber. The wash may be a soluble dye or a transparent pigment such as sienna, umber, vandyke brown or the lakes, ground in water, turpentine or linseed oil, and fixed with glue-size for water staining, or with japanners' gold-size for oil staining.

A satisfactory finish can be obtained only upon sound timber and good joinery or cabinet-work. All foreign matter, such as glue, mortar and plaster, is first removed; the whole surface is then gone over with a cabinet-maker's steel scraper, which cuts off from the softer portions any fur, such as protruding fibre, caused by glasspapering, and gives a flat, smooth surface. The stain, suitably thinned with the appropriate diluent, is applied evenly and plentifully in a regular manner with large brushes.

The softer portions are allowed to absorb as much stain as possible and are then softened off with a soft duster or badger brush; if, however, this destroys the natural markings too much, all excess colour is wiped away with a clean rag. Several coatings of thin stain, with intervals for drying,

retain the natural markings better than one thick coat.

Staining should be followed by a coat of japanners' gold-size thinned with turpentine; this evens up the absorption of the surface before finishing with wax polishing or flat or full-gloss varnishing. See STAINS and VARNISHES.

STAINLESS STEEL. One of a group of alloy steels, containing essentially a minimum of 12 per cent chromium, with additions, for special purposes, of other alloys, notably nickel. These materials are usually classed in three types: martensitic, ferritic and austenitic.

Martensitic. This group is generally of the 12 to 14 per cent chromium type with varying carbon content, from 0·10 to 0·30 per cent, giving a range of ultimate strength from about 30 tons per sq. in. in the softest condition to 100 tons per sq. in. in the hardened and lightly tempered condition, with good ductility.

The group includes a steel containing about 18 per cent chromium and 2 per cent nickel, with better corrosion resistance than the 12 to 14 per cent chromium steels and with a maximum stress of 50 to 60 tons per sq. in. and an elongation of 15 to 25 per cent. The 12 to 14 per cent chromium 0·3 per cent carbon-steel is the material used so widely for table knives and cutting instruments.

Ferritic. A type of stainless steel containing 17 per cent or over of chromium and generally with no other alloy addition. It has better corrosion-resisting properties than the 12 to 14 per cent chromium steel, and is used largely in the United States for sheet-metal articles and for interior decoration. It is easily workable, but will not endure such heavy deformation as the austenitic steels and cannot be hardened by heat treatment. It is cheaper than the latter owing to the reduced alloy content.

Austenitic. This group of steels comprises the well-known 18/8 stainless steel (18 per cent chromium, 8 per cent nickel). In corrosion-resistance these steels are superior to the other two types, and are readily workable, but cannot be hardened by heat treatment. They may be softened after work-hardening by heating to over 1000 deg. C. and quenching in water or air.

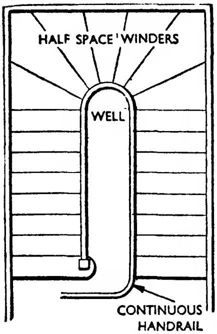
Special types of austenitic steel are made for fabrication by welding; they avoid certain disabilities experienced with the straight 18/8 material. The austenitic steels are the most widely used of all stainless steels, and many thousands of tons a year are consumed in the building of chemical and food plants, and for similar purposes where maximum resistance to corroding influences is of the utmost importance. See AUSTENITE, FERRITE and MARTENSITE.

STAINS. Transparent materials used for altering the colour and tone of timber in order to enhance its natural markings. They are made from crystal dyes, either soluble in water, when they are obtained dry, or soluble in spirit or oil, in which case they are obtained in either paste or liquid form.

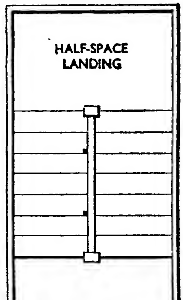
STAIRS. The means of ascent or descent from floors of different levels in a building. Stairs should have a proper ratio of tread to rise, and resting places or landings should be provided between floors.

The usual types of stairs are straight, quarter-turn, dog-leg, open well, and geometrical or continuous; but there are many variations, particularly in detail, including double-return and winding stairs. The illustration shows three typical examples in plan. In modern work it is usual to omit balusters, the balustrade being formed of large panels or made flush, like flush doors. The steps may be fliers, winders, balance, bull-nose, commode, curtail, dancing, and drum or round end.

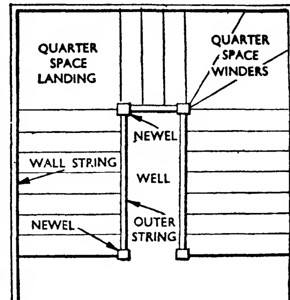
The proportions of the steps vary in both *rise* and *going*, or distance between faces of risers, but in a good flight of stairs the rise should not exceed 7½ in. The going is obtained from the formula: rise × going = about 66, hence a 6½-in. rise requires about 10 in. going. These dimensions



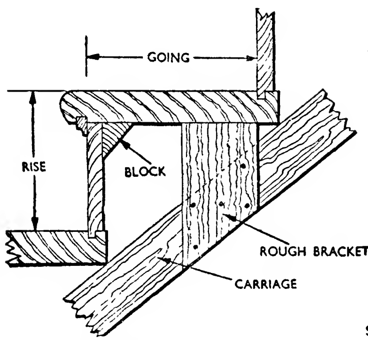
GEOMETRICAL



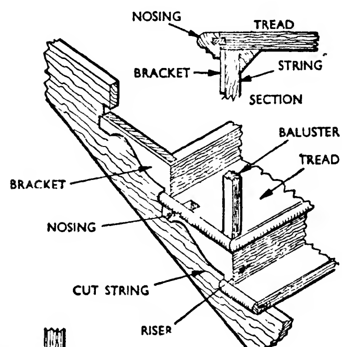
DOG-LEGGED



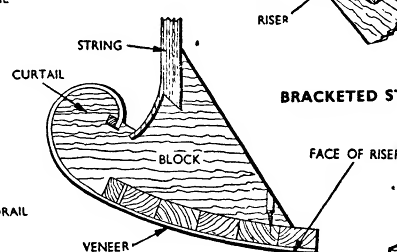
OPEN NEWEL



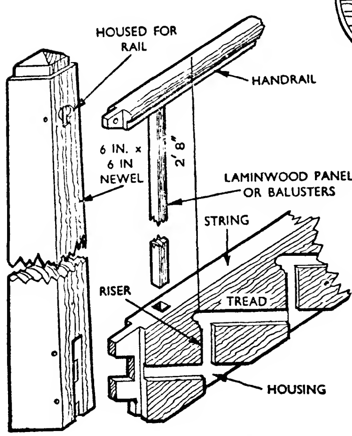
SECTION THROUGH STEP

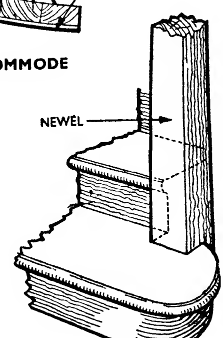


BRACKETED STAIRS



CURTAIL AND COMMODE





NEWEL HANDRAIL AND STRING

ROUND END STEP

Several different types of stairs are in common use in houses and other buildings. Above are shown some characteristic plans and structural details.

are controlled by the position of the stairs, position of door openings and height from floor to floor. The width of the flight should be not less than 3 ft., and the headroom above the face of any riser should be not less than 6 ft. 6 in.

In well-planned stairs there should be landings at intervals to ease the climb. If they are equal to the width of a flight they are *quarter-space*, but if they are across two flights they are *half-space*. When space is limited it is often necessary to include winders, and these may be quarter- or half-space. They are often a source of danger and should be at the bottom of a flight.

The illustration also shows the relative position of the various parts and the method of fixing them together. When the string is shaped to the outline of the steps it is a *cut string*. The string and handrail are tenoned into the newel and fixed by pins. The treads and risers are built up and then fixed to the strings by wedges and glued blocks, as shown by the section through a step. This also shows the *carriage* and *rough bracket*. When the flight is 3 ft. wide or more, a $4\frac{1}{2}$ in. $\times$ 3 in. rough carriage is fixed underneath to strengthen the middle of the steps; and rough brackets, about 5 in. by 1 in., are nailed to the carriage to prevent the treads from sagging.

DOG-LEG STAIRS. These are the simplest type of return stairs. The outer strings of both flights are vertically over each other so that the return string is in the same newel. Very often the half-space landing is replaced by a quarter-space landing and winders.

OPEN NEWEL STAIRS. These are no different in construction from dog-legged stairs, but more newels are required and there is a space between the two outer strings. This depends upon the width of the staircase and the number of steps required.

GEOMETRICAL STAIRS involve many difficulties and demand a high degree of skill on the part of the craftsman. The string and handrail are continuous and the curved part, called the wreath, often requires a knowledge of advanced geometry.

BRACKETED STAIRS may be any of the previous types, as the name is applied merely to the method of returning the ends of the steps on the cut string, as shown in the sketch. The return nosing is often fixed by slot screws. The preparation of the cut string and the mitring of the riser with the bracket require great care.

In superior work it is usual to have one or more specially shaped steps at the foot of the stairs, such as a bullnose, a curtail, or a commode step. The illustration shows a *round-end* step, which has a semi-circular end. If it is only a quarter circle it is a *bullnose* step. In both cases the end is a laminated block, well glued and screwed, which prevents distortion through shrinkage. The riser is cut away to form a veneer round the end. The *curtail* is more difficult to form round the curved part, but the work involved is very similar. The *commode* step is curved along the length of the step and may be applied to any of the previous types.

The illustration shows it with a curtail end. In this case the whole of the riser is built up and veneered. The block, in all three cases, is the full depth of the riser in thickness, less the depth of the scotia.

Winders are usually quarter-space divided into three equal parts on the walking line. This is an imaginary quarter circle 1 ft. 6 in. from the string, and makes the going of the winders, on this line, similar to that of the fliers. The middle winder is called a kite winder. The grain of the wood should run parallel to the nosings. When the winders do not radiate from a common centre they are called *dancing*, or balanced, steps, and are designed to give increased foothold at the narrow end.

STALL. The lift generated by an aeroplane wing varies linearly with the angle of attack, increasing from zero and reaching its maximum value at an angle of attack of 15 or 16 deg.

At this point the streamline flow over the upper surface breaks down, the motion which is supplying the major part of the lift is greatly reduced, and as a result the lift also is reduced considerably.

The point at which this breakdown of flow occurs is called the stall. With some aerofoil sections the stall is very sharp and well defined, while with others the lift gradually falls away with increasing incidence; this, of course, is a very desirable characteristic for an aerofoil section to possess.

STALLOY. A type of silicon steel which is used for electrical laminations because of its low iron losses. See LAMINATION.

STAMPING, see LAMINATION.

STANCHION. A pillar, usually of steel, whose function is to transmit the load of floors and roof to the foundations. The function of a *stanchion base* is to receive the loads from the stanchion and transfer them, uniformly over its whole area, to the concrete foundation, without exceeding the allowable unit-bearing stress in the concrete.

If the end of the stanchion were to rest directly upon the concrete foundations, the latter would tend to crush because the allowable unit compressive stress in steel is much greater than the ultimate compressive stress in concrete.

STANDARD ATMOSPHERE. The earth's atmosphere is in a state of constant change from day to day and from hour to hour, the pressure, temperature and density at any altitude varying over a considerable range of values, though the gas laws are, of course, at all times obeyed.

Now, the power that an engine gives and the drag of an aeroplane vary with these changing atmospheric conditions, so that the performance an aeroplane attains on one day will not necessarily be reproduced on another. It is thus necessary to have an arbitrarily defined set of atmospheric conditions to which all performances may be reduced.

The arbitrary Standard Atmosphere represents roughly average atmospheric conditions, its characteristics being as follows:

Sea level temperature 15 deg. C. or 59 deg. F.
" " pressure 760 mm. or 29·92 in. of mercury.
" " density 0·002378 slugs per cu. ft.

The temperature is presumed to fall linearly with increase of altitude at the rate of 2 deg. C. per 1000 ft. up to 35,000 ft., the assumed lower limit of the isothermal atmosphere, after which it remains constant. The pressure and density at 35,000 ft. are 179 mm. or 7·04 in. of mercury and 0·000736 slugs per cu. ft. respectively. See SLUG.

STANDARD CELL. An electrical standard of e.m.f. in the form of a primary cell which is prepared according to a rigid physical and chemical specification. Such a cell ceases to be standard if any appreciable current is drawn from it.

The circuits in which standard cells are used are arranged so that the e.m.f. is balanced against another p.d. See POTENTIOMETER.

STAND OIL, see LINSEED OIL.

STARCH, see CARBOHYDRATES.

STAR CONNEXION. A method of connecting A.C. electrical circuits, particularly three-phase circuits, so that three or more circuits meet in a common point known as the star point.

STAR-DELTA STARTING. A method of starting induction motors without the use of a separate voltage-reducing device. The three-phase windings are normally delta-connected, but they are connected in star for starting so that each receives 58 per cent of its normal voltage.

As a general rule, the change to delta connexions is carried out by means of a special switch. See DELTA CONNEXION.

STAR POINT, see STAR CONNEXION.

STARTER. The equipment used for starting an electric motor.

The term, as commonly understood, is often restricted to those types of equipment which provide only one running position for the

controls, as opposed to a controller q.v.), which provides two or more.

STARTER MOTOR, see SELF-STARTER.

STATIC. In radio reception, disturbances or noises due to natural causes such as lightning, electrical storms etc. See INTERFERENCE.

STATIC BALANCER. An electrical transformer connected in such a way as to provide a neutral point for a three-phase four-wire system (q.v.) or a mid point for a D.C. three-wire system. In each case it tends to equalize the voltages between the several wires.

STATIC FRICTION, see FRICTION.

STATICS, see MECHANICS.

STATIC STABILITY, see LONGITUDINAL STABILITY.

STATOR. The non-rotating part of an electrical machine.

STEAM COOLING, see COOLING.

STEAM ENGINE. A heat engine, or prime mover in which the heat or energy is applied indirectly to the working parts; i.e. the heat of combustion is first of all transmitted to water in a boiler (q.v.) and then, in the form of steam, to the piston in the cylinder, where the expansive property of steam is transformed into mechanical motion.

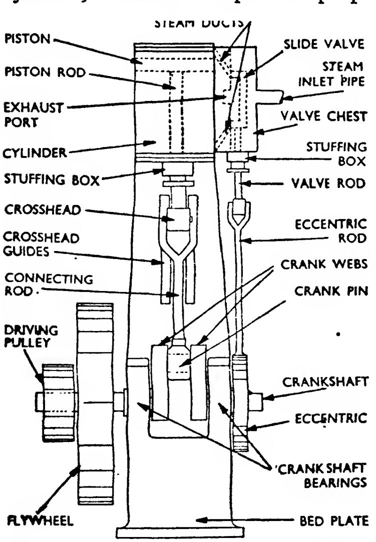


Fig. 1. Simple vertical reciprocating steam engine, illustrating component parts and their respective functions.

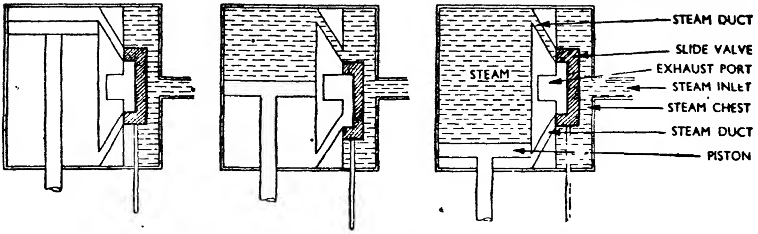
Steam engines have the advantages of great reliability and smooth running together with an extremely large range of power and flexibility, but, on account of the boiler, suffer from a low ratio of power to weight. In small sizes their thermal efficiency is lower than that of the internal-combustion engine but is higher where the plant is large, as in power stations, where means can be taken to use as fully as possible the heat contained in steam. The thermal efficiency of large plants can be as high as 36 per cent.

The modern tendency is to use steam at high temperature, the upper limit which can be reached depending mainly on the materials used in the construction of the plant. Apart from the mechanical stresses involved, high temperature steam tends to penetrate the metal. For this reason attempts have been made to use liquids other than water as a working medium, the best known being the mercury vapour plant in America.

Modern steam engines are of two kinds, *reciprocating* and *rotary*. The former employ cylinders, cranks and flywheels, while the latter are in a class by themselves known as turbines (q.v.). Reciprocating engines are either vertical or horizontal, according to the angle at which the cylinders are set, and single- or double-acting according to whether the steam is admitted to one side only of the piston, or to each side alternately. They are further divided into simple and compound, and condensing and non-condensing.

In simple engines the steam is exhausted, i.e. allowed to escape, after it has expanded in any one cylinder; compound engines employ cylinders of increasing diameter and the steam, after expanding in the first, or high-pressure cylinder, passes on to the next larger cylinder and does further useful work before exhaustion.

Compound engines are thus more economical in their use of steam, but this economy is not apparent until steam of fairly high pressure, say



THREE POSITIONS OF THE SLIDE VALVE

Fig. 2. On the left, both ports are shown covered at the commencement of a stroke. In the centre diagram steam is entering by the upper port, forcing the piston down. On the right, both ports are again covered at the end of the stroke.

200 lb. per sq. in., is used. Simple engines are therefore used with low-pressure steam. In condensing engines the steam is exhausted to a condenser (q.v.) for further use in the boiler, whereas in the non-condensing type it is allowed to escape to the open air. Marine engines are always of the condensing type; locomotives and steam wagons rarely so.

A simple, single-acting vertical steam engine is shown in Fig. 1.

Steam enters the valve chest by means of the steam pipe, which is connected to the boiler. In the valve chest, its pressure helps to keep the slide valve pressed closely against the valve face of the chest. In this face are two ports, inlet and exhaust, connected by channels to the top of the cylinder and the open air respectively. In the position shown, the piston is at the end of the exhaust stroke, and the D-shaped slide valve covers the opening of the connecting channel, which acts as both inlet and exhaust.

As the piston begins to move downward under the momentum of the flywheel, transmitted to it by the crank and connecting rod, the slide valve, operated by the eccentric on the crankshaft, set a quarter-turn in advance of the main crank, also moves downwards and uncovers the inlet port. Steam now enters the cylinder; the piston, subjected to its pressure, continues its downward movement as a power stroke. The slide valve, moving in advance, rises again and covers the inlet port as the piston reaches bottom dead-centre, i.e. the end of its power stroke. As it rises, the slide valve again uncovers the port of the connecting channel, but this time so that the cylinder is connected to the outside air instead of the steam chest, and the expanded steam is thus exhausted. This is the end of the cycle of operations, which then begins all over again.

The operation of the slide valve is more clearly shown in Fig. 2. Here, a steam chest for a double-acting engine is shown with an additional port at the bottom of the cylinder. Note how the slide valve in one

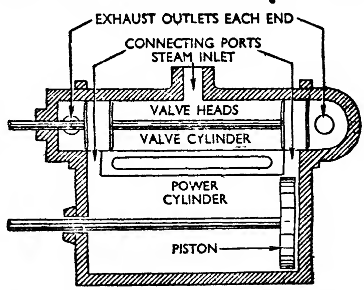


Fig. 3. Working of the piston-valve, employed in high-pressure systems.

movement, shown at (b), connects the steam chest with the cylinder above the piston, and the exhaust with that part of the cylinder below the piston, so that inlet and exhaust are taking place at the same moment.

In large or high-pressure engines the pressure of the steam on the D-shaped slide valve causes too much friction, so that the piston-valve, illustrated in Fig. 3, is used. In this

there are two pistons or plugs on a simple valve rod which works in a smaller cylinder separate from the power cylinder, but connected to the main cylinder by two ports. High-pressure steam enters the valve

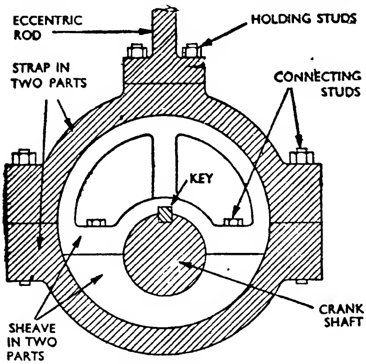


Fig. 4. Essential parts of the normal strap eccentric seen in section.

cylinder between the two pistons, and exerts an equal pressure on each one; there is thus no tendency to force the valve out of position, and it can be moved quite easily by the eccentric rod to connect the two ports, either with the high-pressure steam or separate exhaust ports at each end of the valve cylinder.

The working of the eccentric is shown in Fig. 4. This consists of a cam or disk offset from the centre line of the shaft so that it imparts a to-and-fro motion to the eccentric rod. The amount of eccentricity of the disk determines the length of its throw. Besides operating slide valves, eccentrics are also used for pumps or other devices where a short stroke is required. Around the disk is a strap to which is attached the eccentric rod.

Double eccentrics used for the purpose of reversing an engine and known as Stephenson's link motion are shown in Fig. 5. One eccentric governs the forward movement and the other the reverse. The eccentric rods are connected to opposite ends of a slotted link, this link being movable to right or left by means of a reversing lever. A die or block, sliding in the slotted link, is connected with the slide-valve rod so that when the link is moved the block comes under the influence of one eccentric or the other, the amount of such influence depending on the degree of movement of the link. This results in an alteration in the position of the slide valve in its relation to the steam ports, allowing the steam to enter at either the bottom or the top of the cylinder as the case may be. The eccentrics and link fitted to the slide valve can be seen in greater detail in Fig. 6.

In contrast to the above, what is known as Walschaert's valve gear (Fig. 7), requires only one eccentric, or crank, on the main axle. The expansion link rocks about a fixed pivot, the throw of the valve rod being regulated by the position of the sliding block.

Part of the motion is derived from the action of the crosshead, through the tail piece and combining link. This mechanism is usually assembled on the outside of engine frames and, when so fitted, a return crank takes

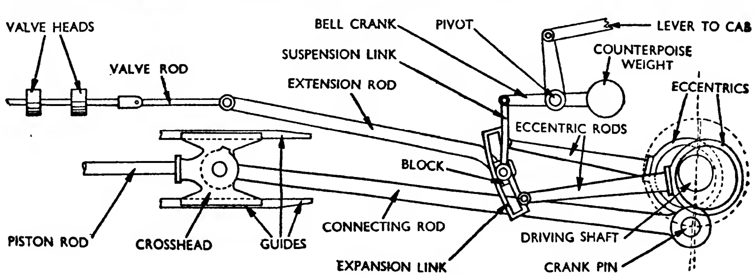
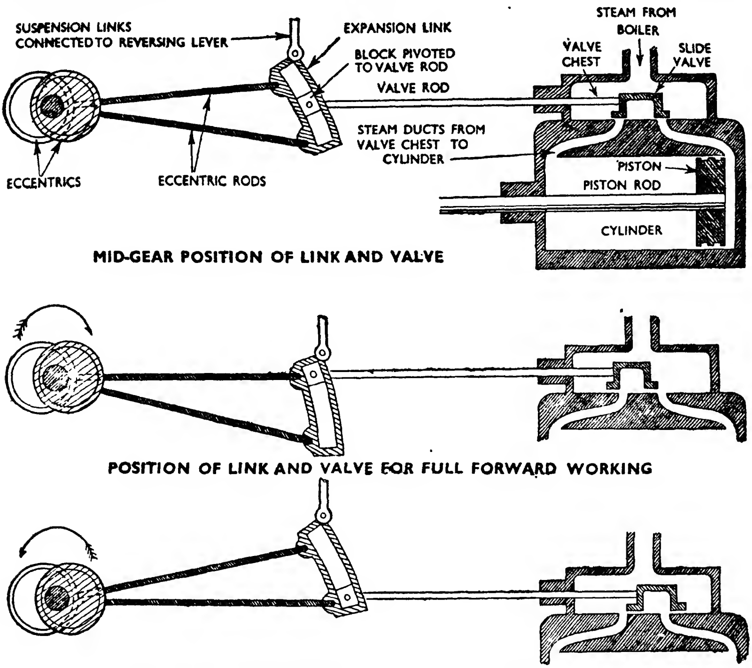
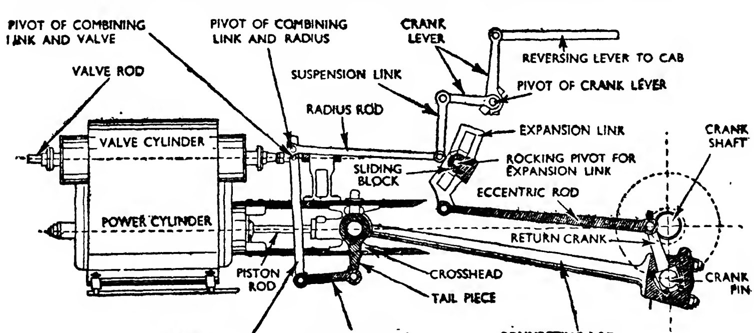


Fig. 5. Coupling of the various parts of Stephenson's link motion. This device of many years' standing employs double eccentrics in order to reverse the engine.



POSITION OF LINK AND VALVE FOR FULL REVERSE WORKING

Fig. 6, above, illustrates the three typical positions in Stephenson's link arrangement, a well-tried device which, for more than a century, has played a vital part in locomotive development and is still in use on hundreds of engines. **Fig. 7,** below, shows in diagram form the more modern Walschaert's valve gear which has now to a great extent superseded Stephenson's system. Since it derives its motion from the crank pin and crosshead, it requires only one eccentric.



the place of the ordinary eccentric. It is secured to the end of the main crank pin, its path being indicated on the accompanying diagram by a dotted circle.

The eccentric rod is pivoted at the end of the expansion link and the position of the die on this link determines the direction in which the locomotive will travel.

Three types of crank for converting the reciprocating motion of the piston

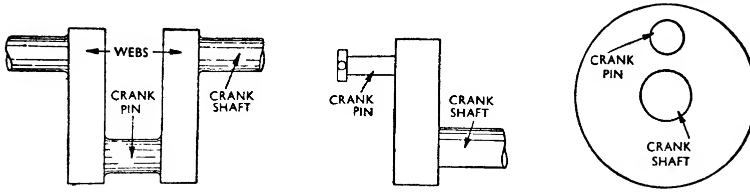


Fig. 8. Three types of crank, which convert reciprocating to rotary motion on a steam engine. On left is shown a double-armed crank, in the centre a simple overhanging crank and on the right a disk crank.

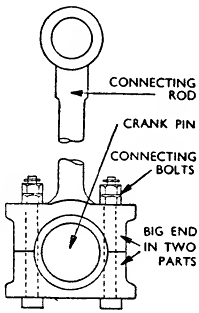


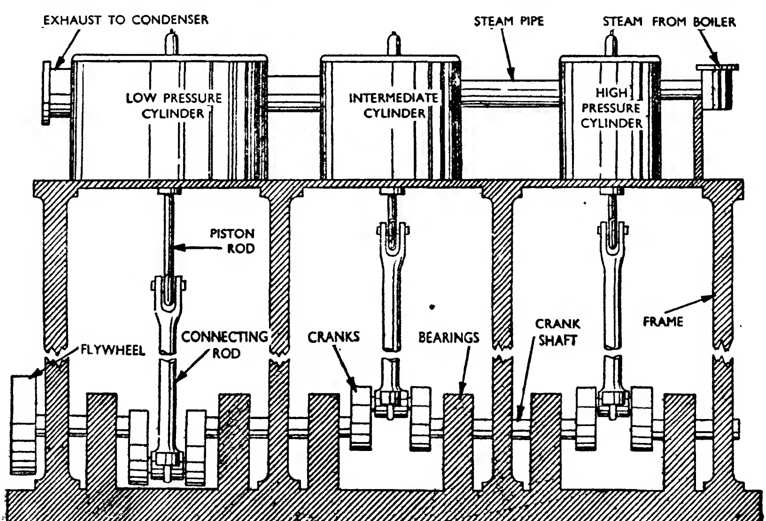
Fig. 9. Main details of a connecting rod, which in steam engine design forms the link between the cross-head and the crankpin.

Fig. 10. How in a triple-expansion engine the steam, entering from the right, passes through each cylinder in turn and thus exerts pressure on the revolving crankshaft three times before being led to the condenser.

and piston rod into rotary motion are shown in Fig. 8, while connecting rod details can be seen in Fig. 9. The big end is usually made in two parts bolted together for easy removal from the crank pin.

In each cylinder of a triple-expansion engine—a simplified diagram of which is shown in Fig. 10—the same original quantity of steam exerts a force on the pistons, the piston rods all being connected to the same shaft. On entering the high-pressure cylinder the steam is probably at a pressure of 200 lb. per sq. in. It exhausts and enters the intermediate cylinder at 75 lb. per sq. in., and passes to the low-pressure cylinder at 25 lb. From there it is exhausted at about 8 lb. per sq. in. to the condenser, where it is converted into water.

In some cases even the remaining heat of the steam, after leaving the low-pressure cylinder, is made to heat the feed water for the boiler



before entering the condenser. The high-pressure cylinder of a triple-expansion engine is fitted with a piston valve, and the intermediate and low-pressure cylinders with flat-faced slide valves.

Should an engine stop at dead-centre, that is, when the connecting rod and crank are in a straight line, no amount of steam pressure in the cylinder will set it going. In single cylinder engines, therefore, steps are usually taken to prevent a stoppage in this position, sometimes by using a weighted flywheel. In double or multi-cylinder engines, however, the difficulty is overcome by setting the cranks at an angle of 90 deg. to each other.

Governors are fitted to most engines to control the running. One type, a centrifugal governor, is illustrated in Fig. 11. It consists of a spindle, at the upper end of which are pivoted two arms or levers, the lower end of each carrying a heavy weight. A grooved collar, capable of sliding up and down the spindle, is connected to

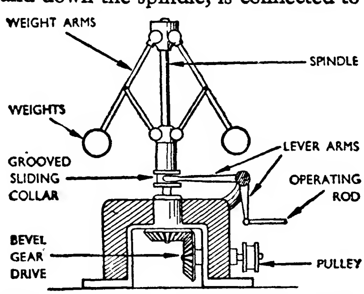


Fig. 11. Centrifugal governor, which controls running of a steam engine.

the weight levers by means of links. The end of a lever fits into the grooves of the collar, the other end being connected to a rod operating the throttle valve in the steam-supply pipe. The governor is driven from the crankshaft either by a belt or by gear wheels, the motion being transmitted to the toothed bevel wheels fixed to the governor spindle.

When the engine is starting from rest, the weights, and therefore the sleeve, are at their lowest position and the throttle valve is fully open. As the engine gains speed, the weights tend to fly apart by centrifugal force and this gradually closes the throttle valve, reducing the amount of steam admitted to the cylinder. Throttling steam, however, is not the most efficient way of reducing speed. Except where a throttle governor is essential, steam should always be full on, and the period of admission governed by accelerating or retarding the cut-off, thus giving the steam a perfect expansion.

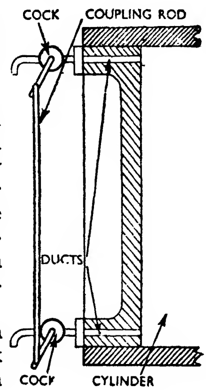


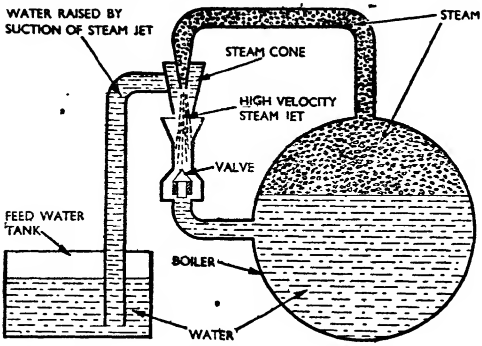
Fig. 12. Cylinder relief cock for draining off water which may accumulate in the cylinder.

What is known as a relief cock (Fig. 12) is an essential component on steam engines. It consists of two taps coupled by rods so that they can be opened simultaneously, the purpose being to drain from the cylinder any water which may have accumulated, either through condensation or through wet steam being carried over from the boiler.

This relief must always be brought into action before starting an engine, live steam being used to drive out the water.

To guard against the damage which might be caused to the cylinder if the relief cocks were not opened, spring-loaded valves are usually fitted to the cylinder covers to relieve the pressure of the steam, should it rise above that of the boiler.

STEAM INJECTOR (Mech. Engineering). Used in locomotives to force water from the feed tank into the boiler and thus maintain an adequate supply. The action of a steam injector is shown in diagram form in the illustration on the next page. When the valve opens, the partial



How high-pressure steam from the boiler of a locomotive forces water from the feed tank into the boiler.

vacuum made by the rush of high-pressure steam from the boiler draws the water up from the feed tank, causing it to flow into the boiler

STEARIC ACID, see FATS.

STEEL CASTINGS. Three grades of steel are included in British Standard Specification No. B.S. 592, Steel Castings for General Engineering Purposes, as in the following table:

Grade of Casting	Yield Point	Ultimate Stress	Elongation	Bend Test
Tons per sq.in.	Tons per sq.in.	Tons per sq.in.	percentage	1 in. × ⅞ in.
35 to 40	17·5	35 to 40	15	90 deg.
28 „ 35	14	28	20	120 „
Non-test	—	—	—	—

The strength of steel is largely controlled by the amount of carbon present, the usual range being 0·15 to 0·40 per cent.

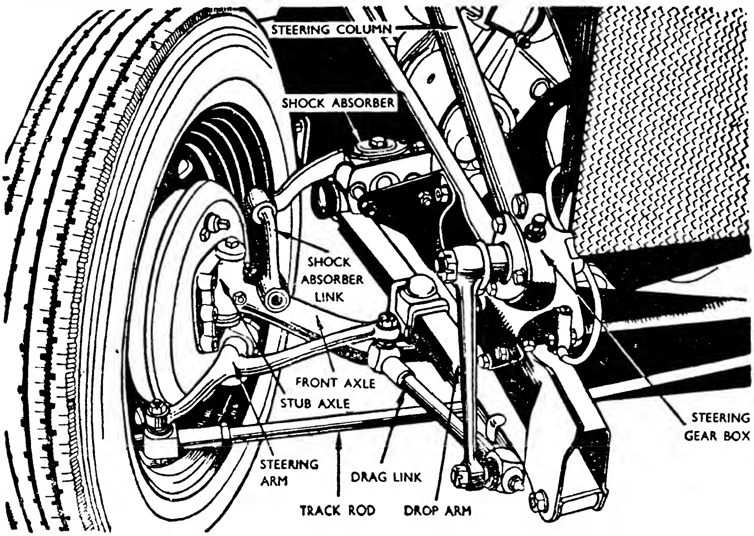
STEEL-FRAME BUILDING. A complete skeleton framework of steel beams and pillars, the framing members being designed to carry the loads of the building, including walls, floors and roof. This type of structure is usually adopted for high buildings containing many floors.

Under some building by-laws the steel members must be entirely encased in concrete, the function of the concrete in such cases being to protect the steel from the effects of fire.

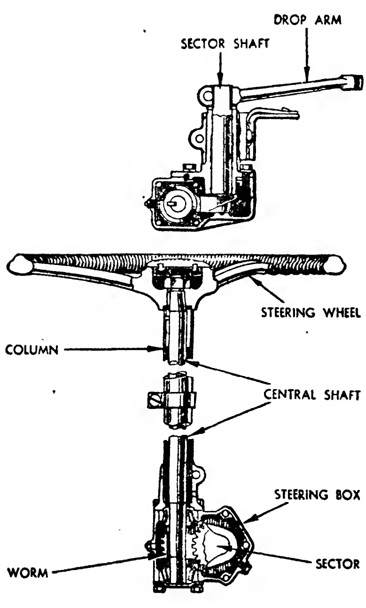
STEERING. The means of controlling the direction of a vehicle within certain limits, as required. The component parts of the steering system of a motor vehicle are the steering wheel, column and the linkage used to convey to the steered road-wheels the movement applied to the steering wheel.

The steering column consists of an outer tube through the centre of which passes a shaft supporting on its upper end the steering wheel, secured by splines or a key and keyway to ensure that the wheel and shaft turn together. On the lower end of the central shaft is a worm-wheel meshed with a toothed sector mounted on a cross shaft positioned at right-angles to the worm. The worm and sector are housed within a casing known as the steering box, which contains the lubricant required for the moving parts. Fastened to the outer end of the sector shaft, which protrudes through a bearing in the side of the steering box, is a drop arm positively secured to its shaft by splines or key. A hardened-steel ball is fitted to the lower end of the drop arm, on which the socket of the drag link fits. The other socket of the drag link fits on the ball attached to the steering arm on the stub axle.

Arrangements of the steering gear are shown in Fig. 1 and the action is as follows:— As the steering wheel is turned the worm rotates, the sector is forced round and moves the drop arm, which transmits the effort to the stub-



Two aspects of the steering gear of a modern car of orthodox design. Fig. 1, above, depicts the components and general arrangement between the steering box and the offside front wheel of a car with right-hand drive. Fig. 2, below, gives a sectional view of details and shows how control is transmitted from the steering wheel.



axle steering arm. As both stub axles are linked by the track rod they move together and the road wheels move in the direction required. The various elements are shown in Fig. 2.

Ackermann system. In the theoretically correct steering gear, a line drawn through the axis of the swivel pin on

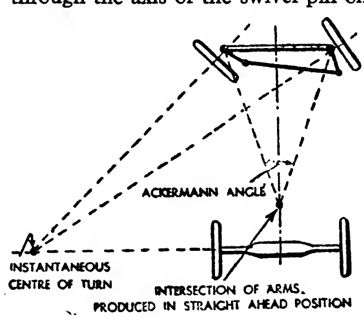


Fig. 3. Ackermann principle of correct alignment for car's steering system.

which the stub axle turns should coincide with a line drawn through the vertical axis of the wheel at the point where both meet the ground. The Ackermann steering principle is illustrated in Fig. 3, which shows how the radii of the paths traced by the front wheels intersect on a line extended from the rear axle. Also, a line

from the centre of the swivel pin to a point near the centre of the rear axle will coincide with the centre of the ball joints of the track rod when the wheels point straight ahead.

The track of the wheels is important if unnecessary wear of tyres is to be avoided and certain points should be checked from time to time. If, when the vehicle is standing, both wheels were set perfectly parallel the tendency would be for them to splay outwards when in motion. To offset this, the wheels are set to toe-in slightly, usually about ⅛ in. To do this provision is made on all steering systems for varying the length of the track rod.

Steering Maintenance. Correct tyre pressure has an important bearing on steering efficiency, and all ball-and-socket joints should be periodically inspected for slackness.

Lubrication of the steering box should be maintained at the level of the filter plug.

STELLITE. A cast and readily weldable alloy composed of chromium, cobalt and tungsten, and containing no iron, but with cutting properties superior to those of high-speed steel. It can be used for the solid tool in small sizes, while for larger tools it can be made into tips for brazing on to a shank of suitable form.

Another method is to use an oxy-acetylene flame to melt the stellite (for this purpose in the form of a rod) on to the shank. No flux is needed for this operation. One of the best features of stellite is that its hardness is not substantially affected by heat up to a temperature of 1500 deg. F.; it is, in fact, tougher when red hot than when cold. Stellite is thus actually at its best when working at high temperatures, especially with high cutting speeds and fairly light feed.

Two important brands of stellite in use in the U.S.A. are known as "J Metal" and "Haynes stellite—2400". The former, which has a hardness at room temperature of 600 on the Brinell scale or 60 to 62 on the Rockwell "C" scale, can be used for machining almost all machinable materials except manganese steel or chilled cast-iron. The latter gives longer tool life than J Metal, permits higher speeds and feeds, and can be used both for roughing and for finishing cast or forged steels, cast-irons, nitrided steels etc.

To give sufficient resistance to the cutting action an angle of about 6 deg. should be adopted for the front rake of stellite tools used on cast-iron, and about 10 deg. when cutting steel.

STENCIL. A perforated plate used for the repetition of a design in the production of borders, friezes and all-over patterns. The fabric of the plate depends upon the size of the pattern, the intricacy of the detail, the medium to be used and its method of application.

Handmade note-paper and drawing paper in sheets, and cartridge paper in rolls, prove satisfactory when the paint is to be applied by brush; for hard wear and when the colour is to be applied by spraying, foil and sheet metals are used. The unit of pattern may be so designed that it may be cut-in and executed with one plate to give a positive rendering, or have the background cut out and so give a negative rendering.

It may, however, be elaborate in detail and require executing in several colours, in which case it is customary for a series of plates to be used progressively to build up a positive pattern; a negative plate may also be required to add a background and leave an outline. In all well-designed stencils the "ties" required to hold the plate together form part of the pattern, and do not require touching up with a pencil afterwards.

Stencil plates may also be prepared for the rapid reproduction of lettering to give both positive and negative renderings.

In normal practice, to obtain the reproduction the plate is held in position and the paint applied through the holes by dabbing with a compact flat-ended brush termed a stencil brush; these vary in size, so that one appropriate to the job in hand may be

selected. The paint used is a quick-drying, fairly thick oil paint.

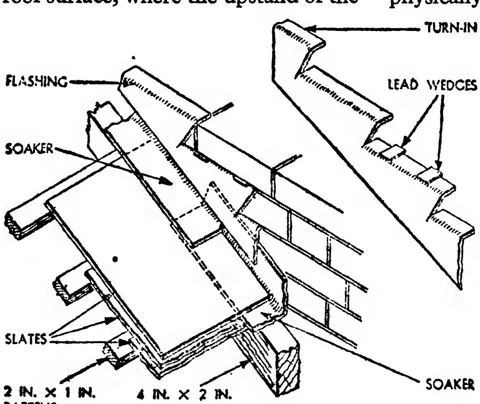
To obtain even colour and clean definition the brush is kept fully, but not excessively, charged with the paint. When using transparent colour, and to obtain graded effects, the stencil brush is not dipped into the colour but is charged by rubbing on a felt pad which is kept coated with the paint. Such effects are, however, best obtained with the spraying equipment.

A closely allied method of developing and executing free ornament is by the use of masks. Interesting shapes are cut out of the same materials as stencil plates. Both the part cut out and the hole left in the plate are used. Orderly arrangements are built up by spraying about and within the shapes with transparent colour which, if allowed to overlap, varies tone.

STEP (Aero. Engineering), see FLYING BOATS.

STEP JOINT, see JOINTS.

STEPPED FLASHING. A means of covering, or overlapping, the joint between a brick wall and a pitched-roof surface, where the upstand of the soakers abuts the brick wall. The flashing metal is cut out to form a series of steps, the rise being equal to the height of the brick courses.



Method of turning stepped flashings into brick joints and, in smaller drawing, position of lead wedges.

The horizontal edges of the metal should be turned into the mortar-bed joints between the brick courses, then secured with lead wedges, and the joint pointed with Portland cement mortar. The bottom edge of the flashing should finish at least ½ in. above the slates, and parallel with the roof surface. See FLASHING.

STEPPED FOUNDATION (Building). A method of construction used to prevent waste of materials and labour on work which is buried, where sloping sites occur. In such cases, the foundations are benched, or stepped, so as to keep the depth of the walls below ground level as nearly uniform as possible.

At the point where the step occurs, the concrete slab of the lower foundation should extend under the slab above for a distance equal to the thickness of the concrete slab.

STEREOISOMERISM. The existence of two or more distinct varieties of a compound owing to a difference in the way the various atoms are arranged in space. For instance, there are two varieties of dichloroethylene. These differ from each other both physically and chemically.

STEREOTYPE. A metal duplicate of type and/or pictures. Almost any number of stereotypes can be made from an original, and they are essential where copies of an advertisement have to be sent to a number of periodicals at the same time, or in newspaper work where a very large number of copies has to be divided between several machines. See ELECTROTYPE.

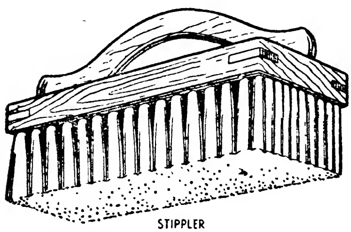
STICKING. When very thin steel sheets are being rolled in packs of two, four, six, eight or, occasionally, more, they are finished in a tight pack which must be separated. If all the variables of steel content, temperature and rolling practice have been correct, the sheets separate easily, with little damage to the surface.

If, however, any of these have been varied, the sticking is so bad that force must be used, sometimes

permanently damaging the sheet. Sheets that have been fastened in the latter way are seldom suitable for best work.

STICK WELDING, see RESISTANCE WELDING.

STIPPLING. The operation of dabbing the wet surface of freshly applied paint to impart a finely granulated texture. The paint is



Normal type of large, flat brush employed for stippling paintwork.

applied in an evenly progressive manner without laying off; the wet surface is then beaten with the ends of the bristles of large flat-faced brushes, shown in the illustration, to obliterate the brush marks and obtain even distribution.

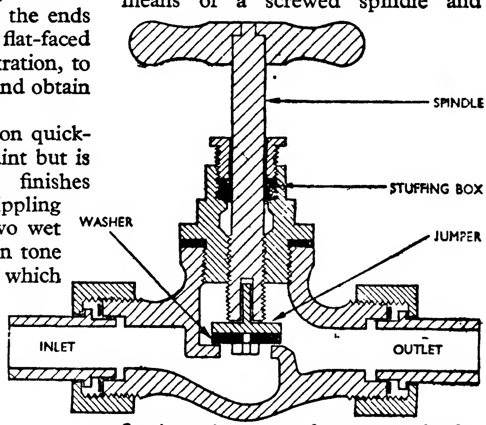
Stippling is employed upon quick-setting oil-bound flatting paint but is not necessary upon flat finishes obtained ready for use. Stippling along the joining line of two wet paints which are different in tone or colour is the means by which even graduation from one into the other is obtained. Transparent-glaze colours are stippled to obtain even distribution and prevent clouding.

Coarsely textured surfaces are produced by beating the wet surface of a reinforced water paint with stipplers in which the hair has been replaced by plates or cylinders of rubber. The stippler illustrated has tufts of fine white bristle inserted into a flat, rectangular wooden back, 6 in. by 8 in., with a bridge handle; this is the normal shape but they may be made long and narrow, or as disks.

The handles also may be an extension at one end of the backing, or adjustable and attached by a thumb screw or a handle which screws into the back at right-angles to it. The type selected for use should be the one best fitted for the work to be undertaken. Hair stipplers are kept in condition by wiping with clean dry rags during their use; they must be washed clean with soap and water immediately the job is finished.

STOKES' LAW. A law defining the rate of fall of a particle through a liquid. If r is the radius of the particle, s its density, s_1 the density of the liquid, η its viscosity, and g the gravity constant, then v, the velocity of the particle, is given by the formula: $v=\dfrac{2r^2(s-s_1)g}{9\eta}$.

STOP COCK. A screw-down valve for controlling a water or steam supply. The diagram shows the principle, which is that of a washer being shut down upon a seating by means of a screwed spindle and



Section diagram of stop cock for controlling water or steam supply.

jumper. The top part of the body contains a stuffing box to prevent leakage when the valve is turned on. As the spindle is unscrewed, the pressure forces up the washer and flows to the outlet.

Stop cocks may be obtained with connexions for lead, wrought-iron or copper tubing.

STOP FERRULE. The stop cock used at the point of connexion where

the water supply to a building is taken from the water main. The cast-iron main is drilled and tapped for the ferrule, and the connexion to the lead pipe is made by means of a wiped soldered joint and brass union. It is used mainly to shut off the supply to a building when necessary.

STOPPING. The material used for filling nail holes and shakes in timber as well as cracks and other small defects in plaster work; the term is also used when referring to the actual operation. After the priming coat is dry all defects are made good with a paste or putty made from the same materials and of similar colour to the paint to be applied, and stiffened with dry whiting.

This stopping is pressed well into the cavity with a stopping or putty knife and all excess removed from the surface.

STOPPING-OFF. In foundry work, the operation of filling-up a portion of the mould which is not required in the final casting. By this means it is often possible to make a modified casting from an existing pattern, but if a number of castings are required it is generally better to make a new pattern, or to make the modifications by means of a core or cores. See STOPPING-OFF PIECE.

STOPPING-OFF PIECE. A template used in stopping-off (q.v.). It is a replica of the desired casting at the point stopped-off.

STORAGE CELL. Synonym for secondary cell (q.v.).

STORM WINDOWS, see WINDOWS.

STRAIGHT-EDGE. An appliance used for levelling and testing surfaces; in woodwork it consists of a piece of wood, usually yellow pine, of any length, having its edges shot, or planed, perfectly true and parallel. In machine-shop work, a straight-edge consists of a flat metal bar, the edges being machined to truly flat surfaces.

STRAIGHT-LINE FREQUENCY. A term applied to a variable radio condenser which, in conjunction with a fixed inductance, causes changes in circuit resonant frequency that are directly proportional to the amount of rotation of the condenser spindle.

STRAIN (Building), see ELASTICITY and STRESS.

STRAIN-AGEING (Metallurgy). An increase in the hardness of an alloy which occurs with time after deformation has taken place. Its effect is to increase yield point, tensile strength and hardness values, and to lower ductility as measured by reduction of area and elongation. Although it is most marked in iron and low-carbon steel it does occur in other metals, but its effect in these is usually so small as to be negligible.

The rate at which strain-ageing proceeds is dependent upon temperature, being lowest at room temperature and highest at higher temperatures. At higher temperatures the optimum hardness comes about in a matter of minutes, following which a reduction in hardness occurs, whereas at ordinary temperatures many months may be necessary to reach the optimum, and the subsequent softening stage does not set in. Rate of hardening is also influenced by the rate of application of the original strain, but the effect of this is not fully understood, since factors not determined by chemical composition can alter or reverse such tendencies.

Although the mechanism by which strain ageing takes place is imperfectly understood it is thought to be analogous to the "precipitation-hardening" which occurs with many aluminium alloys.

The practical effects of this phenomenon may be observed in the working of low-carbon "deep-pressing" steels, which are frequently subjected to a light rolling operation following annealing, to eliminate "stretcher strain" effects during pressing. If such material is stored for a time before pressing, the "strain-ageing" which occurs may be serious enough appreciably to lower ductility.

Since heavily de-oxidized steels are known to be immune to "strain-ageing", non-ageing steels containing aluminium have been marketed which,

it is claimed, can be stored for long periods without detriment.

STREAMLINE. The path taken by any particle of air when its flow past a body is steady, i.e. when it does not contain any eddies. This can be represented by a line and it is thus possible to draw a series of lines which illustrate the flow pattern round the body.

Such lines are called streamlines and the flow streamline flow. The characteristics of streamline flow are that the lines representing the paths of the particles of air are smooth curves, and that they do not cross one another. Each line represents the path of a succession of particles, and gives the direction of the flow at any particular point.

A body so shaped that the flow past it can be represented by streamlines is called a streamline body.

STREAMLINE FLOW, see STREAMLINE.

STRENGTH. The maximum tensile load supported by a tensile test-piece divided by its original area. This value is also known as the *Ultimate* or *Maximum Stress.*

STRESS (Building). An internal resistance that balances an external force. When a force acts upon a structural member, a change will result in the shape or volume of the member. There are three simple forms of stress:

(1) *Tension,* the stress induced in a member when it is subjected to a pull.

(2) *Compression,* the stress when the member is subject to a load tending to compress or shorten the fibres;

(3) *Shear,* the stress when one portion of a member tends to slide over another at a given section, thus creating a cutting action.

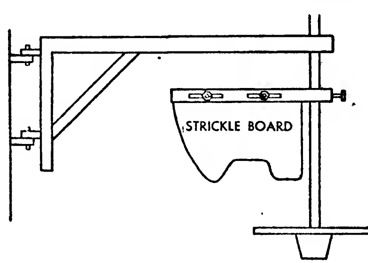
STRESS (Metallurgy). Resistance to loading; expressed in terms of the load and the area under load, e.g. 20 tons per sq. in. Stresses may be produced by external loading; or self-induced, due to differential contraction in cooling, when they are termed internal stresses.

STRESS RELIEVING. A process of heat-treatment designed to relieve stresses produced during manufacture. It is frequently applied to castings, forgings and fabrications and is especially useful, not only to relieve stresses, but to prevent warping if the articles are subsequently to be used at elevated temperatures.

Full stress relieving is obtained by heating steel at 600 deg. C. or cast-iron at 400 deg. C., followed by slow cooling. The prevention of warping during service, however, may be effected by heating to slightly above the service temperature. In all cases, full stress relieving is the most satisfactory method, but it may not always be possible.

STRETCHER LEVELLER. A machine used in sheet-metal work for removing dents and buckles from a sheet surface. Each end of the sheet is gripped in jaws and tension applied, the stretching giving a uniform flat surface. When sheets about to have this treatment are sheared, they are left longer than they will ultimately be required so that the gripper marks may be trimmed off.

STRICKLE BOARD (Foundry Work). A device consisting of a board, set to rotate about a spindle as shown, and used instead of a pattern



General arrangement of strickle board showing how it rotates on spindle.

to make loam moulds. The board, or sweep as it is sometimes called, is profiled along one edge so as to sweep the loam in the mould to the correct section for the shape required.

The edge of the board is square on one side and bevelled on the other; in roughing, the strickle is rotated so that the square edge is leading, while for smoothing, or finishing, it is

rotated once only, the bevelled edge leading. See LOAM MOULDING.

STRIKE THROUGH. The effect, also known as *print through*, of penetration of ink, or vehicle (q.v.), into the paper, to a degree which is visible from the reverse side. It indicates an unsuitable ink/paper combination.

STRING (Carpentry), see STAIRS.

STRINGYBARK, see EUCALYPTUS.

STRIP FEED. A term used in sheet-metal work to describe a method of feeding mechanical presses for blanking from strip stock. The material passes between rollers actuated by an adjustable lever from a stroke-plate on the crankshaft of the press. The position of the lever-setting on the stroke-plate determines the amount of rotation of the rollers and therefore the feed of the stock at each stroke of the press.

The stock movement may be from side to side or from front to back. The lever or ratchet-operated feed can rarely cause a roller rotation of more than 90 deg., so that rack movement is used for long-distance feeding, since several rotations of the rollers can be obtained for one stroke of the machine, and small rollers can be employed. Dial- or rotating-feed devices are employed to give a circular movement to a table which causes the work to move towards or away from the dies; this permits the use of dies for performing one to four operations on stampings on one press.

The advantages of strip feeding include a great increase in production, because the press is able to run at a higher speed, say 200 strokes per min., than hand feeding can maintain. Also, the amount of scrap and idle time are reduced to a minimum, as every stroke is accurately timed, whereas with hand feeding occasional strokes are missed.

Danger to the operator is similarly reduced because there is no necessity for his hands to be anywhere near the die. One operator can easily attend to several machines without fatigue. On an inclined press, a chute provides a simple automatic method of feeding strip stock of limited length, the blanks falling at the rear of the machine clear of the die.

STRIP METAL. Usually differentiated from sheet metal by width; it is commonly agreed that strip metal becomes continuous sheet when over 24 in. wide. Strip metal may be fully hot-rolled or may be finished in cold rolls, the latter material having the necessary physical properties for such further work as pressing and rolling into sections.

It is usual to specify hot-rolled strip as with "rolled edges" or "sheared edges"; in the latter case multiple widths may be rolled and the finished widths achieved by means of gang-slitters (q.v.). All the non-ferrous metals, as well as stainless steel and mild steel, are obtainable in strip form, and it is now possible to have strip steel electro-galvanized after mill finishing.

In order to take full advantage of the reduced handling costs for coils as compared with individual blanks, strip-feed devices may now be fitted to suitable presses.

STRIPPING PLATE. A special plate used in foundry work with some plate patterns to prevent damage to the mould when the pattern is drawn. The device is valuable for patterns with large vertical surfaces penetrating far into the mould. The stripping plate should fit the pattern closely. It is left in place when the pattern is drawn, thus preventing damage to the top surface of the mould. The pattern must be made longer, according to the thickness of the stripping plate.

STROBOSCOPE. A device for making a moving object appear stationary. It may consist of a shutter, through which the object is viewed, or of a means of illuminating the object by a series of flashes of light.

In either case the timing is so arranged that a given point on the rotating object is in the same position each time it is viewed or illuminated. If the timing is slightly in error the object appears to rotate slowly.

STRONTIUM (Sr). Atomic no. 38; atomic wt. 87·63. A silvery-white

metal, melting at 810 deg. C. and boiling at 1940 deg. C. Density 2·50. It belongs to the same group as calcium and barium, and resembles them chemically.

Strontium is also dibasic, forming the carbonate, $SrCO_3$, which is found as the mineral strontianite; and the sulphate, $SrSO_4$, which occurs as the mineral celestine.

Strontium chlorate, $Sr(ClO_3)_2$, is used in making fireworks to produce a red flame. Celestine is used for the same purpose.

Strontium hydrate, $Sr(OH)_2$, is used in the manufacture of beet sugar to assist the crystallization of the sugar from the molasses.

STRUCK JOINTS, see POINTING.

STRUCTURAL GLASS. Glass units used as a walling material. Walls built of glass bricks are becoming common in modern building construction.

Although units of this type are considered to be non-load-bearing, their relative compressive strength makes them eminently suitable for external panel walls and interior partition walls.

The modern development of glass units and lenses is the setting of small glass squares or disks in reinforced concrete frames. This is possible owing to the fact that the coefficients of expansion of glass and concrete are almost the same.

STRUCTURAL STEEL. Rolled shapes of mild steel, known as "steel sections", used for structural purposes in the construction of buildings. The usual sections are: I-beams, tee-sections, angles, channels, and flats or plates. The I-section, the most commonly used, comprises a top and bottom flange and a separating web.

This form is economical in material, because the largest proportion of the material is concentrated in the flanges where the stresses are greatest.

Structural steel is subject to standard requirements laid down in British Standard Specifications (B.S.S.). The sections are produced by passing white-hot steel through a rolling mill, the resulting shapes being termed "rolled-steel" sections.

STUB TENON (Carpentry), see JOINTS.

STUD PARTITION. A wooden partition which is based on a frame of rough timber; used in carpentry.

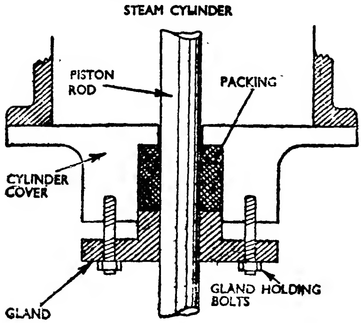
STUD WELDING. A process of affixing studs or tubes to plates by means of an electric current. Generally the process is used for affixing screwed studs of brass to steel plates, such as the bulkheads of ships, the studs being used to locate saddles for cables, lamp brackets etc.

This method is very much more rapid and more economical than the old arrangement of drilling, tapping the plate and inserting the stud. The power-supply required is D.C. from 60/100-volt mains or from a drooping-characteristic arc-welding generator set.

To carry out a stud weld, the stud is gripped in a chuck connected to the supply and brought into contact with the plate at the point where the stud is to be affixed. The stud is withdrawn about $\frac{1}{32}$ in., and an arc is formed between the base of the stud and plate and allowed to continue for about half a second (depending on current and stud size). The arc is extinguished by pressing the stud into close contact with the plate (the upset pressure), thus finishing the weld.

With modern arc-welding generator sets, studs from $\frac{1}{4}$ to $\frac{1}{2}$ in. diameter may be welded on steel from $\frac{1}{16}$ in. thick upwards. Steel studs may also be welded, but higher currents and pressures are required than with brass. It should be noted that the process of stud welding is really an arc-welding one, the pressure merely consolidating the weld and pushing out the oxides and impurities.

STUFFING BOX. On a steam engine, a box attached to the casing at that end of the cylinder through which the piston rod passes, to prevent the leakage of steam from the cylinder. It is packed with suitable material which, when a gland is screwed in position, as shown in the accompanying sketch, exerts a pressure on the



How the stuffing box prevents steam from leaking past the piston rod.

piston rod and consequently seals the joint. An arrangement similar to this is provided for the slide-valve spindle where it enters the valve chest.

SUBLIMATION. The process by which solid substances, such as iodine and camphor, on being warmed, vaporize before becoming liquid. The vapour is collected on a cold surface.

SUB-STATION. A collection of electrical equipment wherein electrical energy is changed in form. It may be changed from A.C. to D.C. or may undergo a change of voltage, as in a transforming sub-station, or of frequency.

SUCROSE, see CARBOHYDRATES.

SULPHATE. A salt of sulphuric acid (hydrogen sulphate or oil of vitriol, formula H_2SO_4). The acid is made almost exclusively by two methods, the "contact" and "chamber" processes. There are three classes of sulphate: acid sulphate or bi-sulphate, normal sulphates and basic sulphates. Some sulphates occurring naturally are of great importance, such as heavy spar, $BaSO_4$; gypsum, $CaSO_4.2H_2O$; celestine, $SrSO_4$; and Epsom salts, $MgSo_4.7H_2O$.

Most normal sulphates are soluble in water, being well crystallized with water of crystallization, but those of lead, barium and strontium are practically insoluble in both acid and water. Many bivalent sulphates crystallize well with water of crystallization, and are known as vitriols; the name is derived from the Latin *vitriolum* (piece of glass), as they were among the first-known transparent crystals. Among them are copper sulphate, $CuSO_4.5H_2O$ (blue vitriol); ferrous sulphate, $FeSO_4.7H_2O$ (green vitriol); and zinc sulphate, $ZnSO_4.7H_2O$ (white vitriol).

Two acid sulphates of great importance are those of the alkali metals: potassium bi-sulphate, $KHSO_4$, and sodium bi-sulphate, $NaHSO_4$.

SULPHATING. A form of deterioration of a lead-acid accumulator (q.v.) whereby insoluble lead sulphate is deposited on the plates.

SULPHUR (S). Atomic no. 16; atomic wt. 32·07. A yellow solid that exists in two different crystalline varieties; it can also be made in a plastic form that gradually becomes crystalline. The most stable variety consists of rhombic crystals with a density of about 2·05; it melts at 112·8 deg. C. and boils at 444·7 deg. C. Sulphur is a mixture of three isotopes of masses of 32, 33 and 34, of which the first forms 96 per cent. of the whole.

In a finely divided form, sulphur is largely used for spraying crops, particularly vines. It is obtained in considerable quantities from underground deposits in the U.S.A. by means of bore holes, through which is forced superheated steam which melts the sulphur. The molten sulphur is forced to the surface by means of air-pumps.

Sulphur is hexavalent and forms two oxides, the dioxide SO_2 and the trioxide SO_3. The latter dissolves in water, combining with it to form sulphuric acid, H_2SO_4, a powerful and important acid that when brought into contact with metals converts them into sulphates. Sulphate of iron, $FeSO_4$, copper sulphate, $CuSO_4$, and sodium sulphate, Na_2SO_4, are well known.

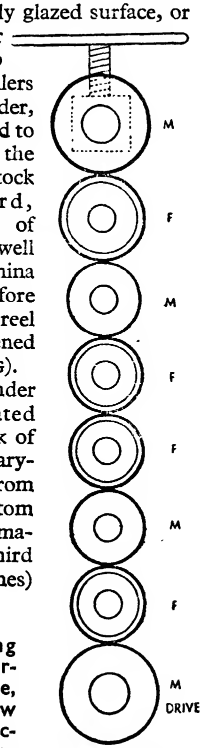
Sulphuric acid is made in two ways, the lead-chamber process and the contact process. In the former, sulphur dioxide and air with nitric oxide, NO, fumes are introduced

into a leaden chamber and sprayed with water; the NO helps the oxygen of the air to combine with the sulphur dioxide, forming the trioxide, which combines with the water to make the acid.

In the contact process, carefully purified sulphur dioxide and air are led over a heated platinum or vanadium catalyst, where the sulphur trioxide is formed; it is then led into dilute sulphuric acid until the desired strength is obtained. Sulphuric acid is very largely used in the manufacture of dyestuffs and other branches of industry. Calcium sulphate occurs as the anhydrite, $CaSO_4$, in various localities, and as gypsum, $CaSO_4.2H_2O$, in other places. If gypsum is heated it is converted into a hemihydrate, $2CaSO_4.H_2O$, known as Plaster of Paris (q.v.).

SUPERCALENDERING. The production of a highly glazed surface, or surfaces, on paper by passing the web between the rollers of a supercalender, sometimes referred to as S.C. To obtain the best results the stock should be hard, closely knit and of even texture, well loaded with china clay and sized. Before calendering, the reel is evenly moistened (see CALENDERING).

The supercalender machine illustrated consists of a stack of rollers or bowls varying in number from 6 to 16. The bottom roller in small machines (and the third in large machines) is driven by power, and the rest by friction. Highly burnished metal rollers alternate with compressed paper or cotton-covered rollers, except that the two middle rollers are of the same material when it is required to treat both sides of the web in the same way. The paper passes upwards between each set of rollers successively and under considerable pressure. Such treatment renders the paper more compact, but increases the translucency.



F FABRIC COVERED
M BURNISHED METAL

Diagram showing end section of supercalendering machine, illustrating how metal and fabric-covered rollers occur alternately.

SUPERCHARGER. An air pump fitted to an internal-combustion engine to supply an air/fuel mixture at a pressure greater than atmospheric.

The power that a normally aspirated engine delivers falls off rapidly with increase of altitude, because the power is a function of the mass of air consumed in a given time at a constant rate of revolution. This is less at altitude than at sea level because both the density and the pressure of the air are less.

It is therefore common practice to fit a supercharger to the engine of an aircraft to maintain the pressure of air (together with the petrol vapour in the induction manifold) at its sea level value; this prevents the power from falling off, the pressure being maintained up to the altitude at which maximum performance is required, which at the present time can be 20,000 ft. or more.

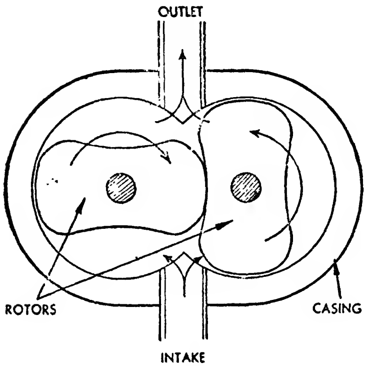
Superchargers are also used to raise, above sea-level pressure, the pressure of the air in the induction manifold, both at sea level and at altitude, in order to obtain more power for a given size of engine.

Superchargers may be of two kinds: the displacement type, shown in the illustration, of which the Rootes model is a well-known example, and the centrifugal type. Because of its bulk the former is suitable only for small engines while the latter may be used on engines of all sizes.

It has been the standard practice for some years to drive the supercharger through a suitable chain of gears from the crankshaft. The power required to drive the supercharger is

quite large, so that the power delivered to the propeller is appreciably less than the total power generated by the engine.

There is a considerable amount of energy going to waste in the engine exhaust, and there has been a growing tendency of late to utilize part of this



Rootes blower, a type of supercharger used to boost the power of small aero-engines and racing-car engines.

energy to drive the supercharger by means of a turbine. This has been made possible because of the progress that has been made in finding suitable alloys, that will stand up to the high exhaust-gas temperatures, for the turbine blades.

The turbo-supercharger, or turbo-blower as the turbine-driven supercharger is called, is mechanically quite simple; the exhaust gases are led to a single-stage turbine (that is, a turbine with a single row of rotating blades) which is coupled direct to the rotor of the supercharger. A valve is arranged so that varying amounts of the exhaust gases can be by-passed to the atmosphere, in order to regulate the speed of the turbine.

At the present time neither the mechanical supercharger nor the turbo-supercharger can claim a distinct advantage. At high speeds just as much energy can be reclaimed from the exhausts by ejector exhausts on an engine with a mechanical supercharger as by a turbine, so that the net thrust-power is about the same in both cases. For cruising conditions, where ejector exhausts are not nearly so efficient, it is probable that the turbo-supercharger will be distinctly more economical, particularly at high altitudes. See VOLUTE.

SUPERHEATED STEAM. Steam which has been heated above the temperature necessary to maintain its form as water vapour. There is no limit to which steam can be heated; superheated steam will make copper tubing red-hot, and set fire to anything inflammable. For this reason all lagging and packing in a superheated-steam plant must be of non-inflammable material. Superheated steam is more economical in large plants, and is sometimes used in central-heating systems.

SUPERHETERODYNE RECEIVER. The name given to a radio receiver which operates on the supersonic heterodyne principle. Such an arrangement differs from the T.R.F. (tuned radio-frequency) receiver in that, after the signal is initially received, its original radio frequency is changed to another fixed frequency and then amplified before demodulation. This new frequency is known as the *intermediate* frequency and the associated amplifier becomes the "I.F. amplifier". This system offers many advantages.

The frequency of any station desired can be converted to this new I.F. and all radio frequency amplification can thus be effected at a predetermined frequency. In such circumstances, and since the I.F. amplifiers are fixed-tuned and can be designed to suit requirements, the overall selectivity and stage gain will be independent of the wavelength of the station received, unless there is any initial amplification at signal frequency. The only circuits tuned to the original signal will be those at the aerial end of the set. They need not exceed two in number and will generally consist of a band-pass arrangement.

A block diagram showing the main parts of a superheterodyne receiver is given at Fig. 1 overleaf, the

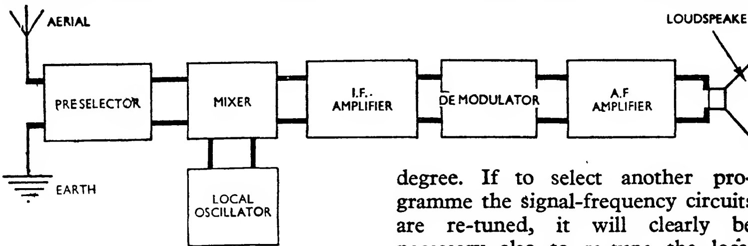
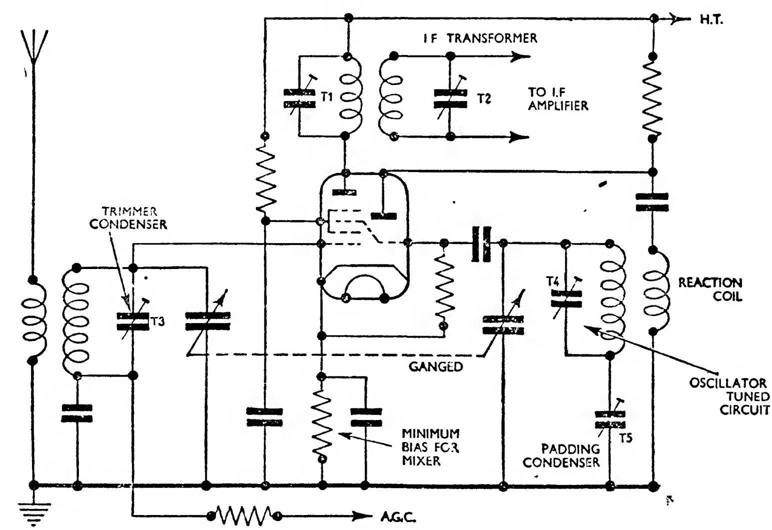


Fig. 1. Sequence of the main sections of a typical superhet radio receiver.

working principle being as follows: The signal from the aerial is selected by an R.F. tuned circuit or *pre-selector* and, in elaborate sets, may undergo amplification at this stage. The *mixer* or *frequency-changer* then acts on the signal in such a manner as to change its frequency to the I.F. The production of this new frequency involves the heterodyne principle, the "beat note" being supersonic and, in fact, the I.F.

The signals, now at I.F. and still bearing the original "intelligence", are amplified to any desired or necessary degree. If to select another programme the signal-frequency circuits are re-tuned, it will clearly be necessary also to re-tune the local oscillator so that the difference between the oscillatory frequencies of these circuits shall be equal to the I.F. The tuning condensers concerned are, therefore, ganged and circuit arrangements are made so that this constant-frequency difference exists at all times.

The next stage may be a simple conventional demodulator but is more often a complex arrangement simultaneously providing demodulation, audio-frequency amplification and A.G.C. voltage. This A.G.C. biasing voltage is applied to the grid circuits of the pre-selector amplifier (if any), I.F. amplifiers and the mixer section



CIRCUIT DIAGRAM OF FREQUENCY-CHANGER SECTION

Fig. 2. Aerial and oscillator tuning condensers are ganged. Maintenance of the constant frequency difference is ensured by initial adjustment of the "padding" condenser T_5 and trimmers T_3 and T_4. Anode load of the mixer is a band-pass arrangement, T_1 and T_2 being pre-set condensers to tune windings to the chosen I.F.

of the frequency changer valve (Fig. 2). The last link in the chain follows usual practice and includes the power-output valve.

The circuit diagram of the frequency changer section of a superhet receiver is given in Fig. 2. The valve employed is a triode-hexode in which the hexode functions as mixer and the triode provides the locally generated oscillations. The oscillator section provides its own bias by means of a suitable grid leak and condenser, and a fixed resister in the cathode circuit of the mixer ensures a minimum bias so that in the absence of A.G.C. voltage its grid shall be not driven positive with respect to its cathode.

The double-diode triode (Fig. 3), apart from providing signal demodulation and audio-frequency amplification, develops across R_1 a D.C. voltage depending on average carrier amplitude. It is this voltage, decoupled and smoothed by R_2 C_2 and R_3 C_3, which is applied as negative grid bias to the I.F. amplifier and mixer valve respectively. In order that this bias is not operative on weak signals, it is prevented from coming into action until signals reach or exceed a given value by the voltage across R_6, and the A.G.C. is said to be delayed; R_4 and R_5 ensure that a minimum standing bias is always provided.

Many factors, particularly those concerning interference and stable amplification, determine a suitable intermediate frequency. From the interference point of view, there are two main requirements. First, suppose the choice of I.F. to be 110 kc/s (at which frequency, amplification is easy) and that the incoming signal is at 1000 kc/s. The local oscillator will then be operating at 1110 kc/s.

Should there be a station working on 1220 kc/s and the pre-selector circuits permit its signal to reach the frequency changer, the 110 kc/s I.F. will be produced (1220−1110=110). Two transmissions, therefore, pass to the I.F. amplifiers; the unwanted one may even beat with the wanted one, producing an audible whistle or note. This effect is known as *second-channel* interference, and can be minimized by having good pre-selector circuits and making the I.F.

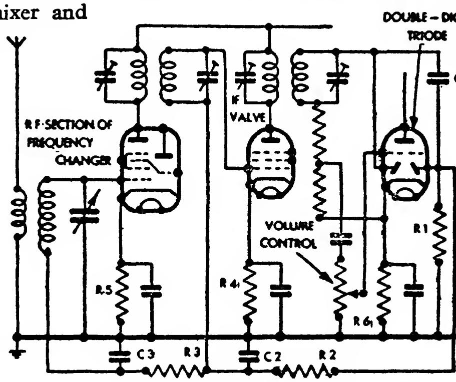


Fig. 3. Skeleton circuit showing how automatic gain control voltage is fed back to mixer and I.F. valves.

fairly high. Secondly, difficulties can be encountered also if the I.F. be too high.

Apart from the problems of obtaining adequate and stable gain at high frequencies, there is the following possibility. Suppose there is a strong station on 30 metres (10,000 kc/s), and that, as is usual on short waves, the input circuits of the receiver are not highly selective. Let the I.F. be 450 kc/s. As the set is tuned over the band, the local oscillator will pass through both 10,450 kc/s and 9550 kc/s, and thus the station will be heard apparently on about 33 metres as well as 30. The spurious signal on 33 metres is said to be an "image".

The choice of I.F. is also governed by the nature of the received signal, particularly its modulation frequency. If the I.F. signal is faithfully to bear the original intelligence, the selected I.F. must be many (say ten) times the highest modulation frequency it is desired to handle. This is particularly important in television reception, where modulation frequencies can be

of the order of megacycles per second.

The ability of a superheterodyne receiver to reject signals that are close in frequency to the required one, is controlled almost entirely by the characteristics of the I.F. tuned circuits which determine, therefore, what is called *adjacent-channel* selectivity.

A complete survey of all the design considerations in a superheterodyne receiver would be very complex, but the advantages of such a receiver may be summed up as follows: Large R.F. amplification gains can be provided, giving great sensitivity for all signal frequencies.

It follows that adjacent-channel selectivity, which is the same on all wavelengths, may be determined at will by the designer.

SUPERSONIC FREQUENCY. A frequency in radio, above the audible limit. See INTERMEDIATE FREQUENCY.

SUPPRESSOR GRID. A grid interposed in a pentode radio valve between anode and screen grid and usually connected to cathode. It is so called because of its apparent effect on secondary emission. While it does not literally suppress such emission it is able, by virtue of its relatively negative potential, to cause secondary electrons, liberated by the anode, to return to the anode rather than travel to the screen grid.

SURFACE CONCRETE. A layer of concrete—sometimes termed "site concrete"—having a minimum thickness of 4 in., which is spread over the ground between the walls of a building and under timber ground floors, thus covering the whole of the floor area. The provision of this concrete layer is compulsory under most building by-laws.

The object of the surface-concrete layers is to prevent ground gases rising into the rooms of buildings; they should therefore be formed with fine aggregate Portland cement concrete, and the top surface of the concrete should be rendered dense by being finished with a trowel.

SURFACE TENSION. In a volume of any liquid the molecules of the liquid are attracted to each other. The molecules at the surface of the liquid are pulled inwards by molecules in the interior, so that there is a net force tending to reduce the area of the surface to a minimum.

The liquid thus acts as if it were enclosed in an elastic bag, under tension. The resulting force in the surface is referred to as the surface tension.

SURFACING (Mech. Engineering). The operation of surfacing may be defined as the facing of a workpiece in a lathe; it is therefore a variety of turning in which a flat surface is produced at right-angles to the axis of rotation. The process is often called "facing" (q.v.), and where there is sufficient work of this character to justify it a workshop may be provided with specially designed "face lathes".

These machines are somewhat like the "gap" lathe, but have no fixed centre in the headstock, and usually no tailstock, since the work is supported only by the faceplate.

Pulley wheels, flywheels and wheel tyres are the principal classes of work for such lathes, the operation of which is chiefly restricted to workpieces in which the "depth" (axial measure) is small in relation to the diameter. Some face lathes are modified to include a boring bar which can slide in a bush at the centre of the faceplate.

In such cases the change-speed cones and back-gearing for the boring bar are located where the tailstock would be in a normal lathe. Lathes of this kind have been built with faceplates up to 9 ft. in diameter.

A smaller variety of face lathe is furnished with a chuck instead of a plain faceplate, and is sometimes known as a chuck lathe.

SURGE. A transitory electrical disturbance travelling along a conductor. Lightning is one well-known cause of surges.

SURGE DIVERTER, see ARRESTER.

SUSPENDED CEILINGS. Plain or ornamental surfaces which are formed or hung some distance below

the underside of floor slabs and beams. The objects of suspended ceilings may be summarized as:

(1) to cover the irregularities of the underside of floor slabs;

(2) to give accommodation space for service pipes and ducts;

(3) to produce a level ceiling surface and to give better proportions to a room; and

(4) to assist in insulating concrete-roof slabs, thereby preventing the accumulation of condensing moisture on the under surface of such slabs.

Suspended ceilings, when constructed in combination with timber floors, are held in position by a system of firring (q.v.). When in combination with concrete and hollow-block floors, they are suspended by metal hangers and horizontal bars, tubes or tee-sections, which in turn are wired, or connected to the hangers.

SUSPENSION. A mixture of finely divided particles floating in a liquid and remaining suspended in it. Many paints and emulsions are in a state of suspension, and fine clay makes a suspension in water.

SWAGING, see POWER PRESS AND PUNCHING MACHINE.

SWAN-NECK CHISEL, see CHISEL.

SWEATING, see TINNING.

SWEEPBACK. The angle between the lateral axis of an aircraft and the projection of the leading edge of the wing in the plane of the lateral and longitudinal axes, as shown in the diagram.

The objects of sweepback are to bring the centre of pressure of the wings farther back in cases where it is necessary to decrease the stalling movement, and to provide lateral stability.

In the aircraft shown, if the right-hand wing drops, causing a sideslip to the right, the effective aspect ratio of this wing will become greater than that of the other, making it aerodynamically more efficient. The right-hand wing will thus produce more lift than the left-hand wing, restoring the aircraft to an even keel.

SWING DOORS, see DOORS.

SWITCH. An apparatus for opening and closing an electrical circuit. The term is often restricted to non-automatic apparatus. See CIRCUIT-BREAKER.

SWITCHBOARD. An assembly of electrical switchgear (q.v.).

SWITCHGEAR. A general term for equipment used for the control of electricity.

SYCAMORE. A wood with a clean white appearance, in some respects similar to maple. It has a fine, even grain, and is hard and tough. Some rift-sawn sycamore gives a beautiful mottle used for high-class joinery, but it is used chiefly for kitchen fitments, butchers' fittings etc.

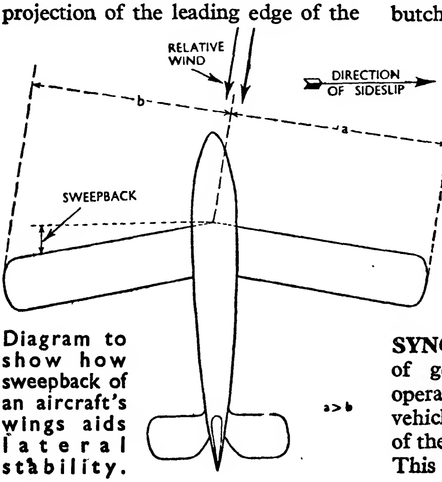


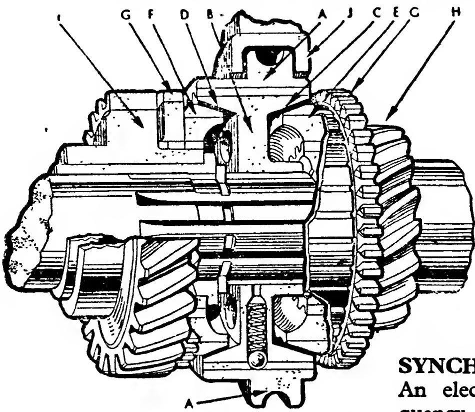
Diagram to show how sweepback of an aircraft's wings aids lateral stability.

SYMMETRICAL COMPONENTS. The three sets of electrical vectors into which an unbalanced set of three-phase currents or voltages can be analyzed. The positive- and negative-sequence components are balanced sets of vectors having opposite phase sequence (q.v.), while the zero-sequence components consist of three equal vectors in phase with one another.

SYNCHROMESH GEARS. A type of gearing used to simplify the operation of gear-changing on motor vehicles by synchronizing the speed of the two gear-wheels to be engaged. This is achieved by first bringing

them into frictional contact until their speeds are the same.

The illustration shows a top- and third-gear mechanism of this type. The coupling comprises two members A and B which are located together by spring-loaded balls. There are usually six of these, but only one is shown. The inner member B has two cones, C and D, which must first come into



Mechanism of top and third ratios in a synchromesh gearbox. This is the most extensively used device on motor cars for assisting changes from one gear ratio to another.

frictional contact with gear-wheel cones E and F before the teeth on the inside of sleeve A can engage with those on the outside of wheels H and I.

To engage top gear the selector fork J is moved to the right, thus exerting a pressure on A. A in turn slides B along the central splined shaft, through the medium of the steel balls, until cone C engages cone E. Increasing pressure by J synchronizes the speed of the two wheels, and A continues its movement to engage the teeth G, which it does by depressing the balls against the springs. To disengage top gear and engage third, the selector is moved over to the left, and the same operation is repeated on the other side until G on wheel I is engaged.

SYNCHRONISM. The electrical condition wherein two or more pieces of electrical equipment maintain the same phase relationship, if there is no change of load or other external condition.

For example, two alternators running in parallel are in synchronism; if the load changes the relative phase-angle changes but again settles down to a constant value. If it does not, then synchronism is lost and parallel operation is not possible.

SYNCHRONOUS CONDENSER. A synchronous electric motor running unloaded with its excitation so adjusted that it draws current at a leading power factor (q.v.). In this way it may be used to counteract the lagging power factor of other machines.

SYNCHRONOUS CONVERTER. Synonym for rotary converter (q.v.).

SYNCHRONOUS GENERATOR. An electrical generator whose frequency depends only on rotational speed and the number of poles. All normal alternators are synchronous generators. See SYNCHRONOUS SPEED.

SYNCHRONOUS IMPEDANCE. The equivalent impedance of a synchronous electrical machine, by means of which account may be approximately taken of armature reaction as well as reactance. The synchronous impedance is obtained by dividing the e.m.f. which is given on open circuit by the normal field current, by the short-circuit current produced by the same field current.

SYNCHRONOUS-INDUCTION MOTOR. An electric motor which may run either as an induction motor or as a synchronous motor, according to circumstances, for instance, load. See MOTOR.

SYNCHRONOUS MOTOR. An electric motor whose speed is determined only by the frequency of the supply and the number of poles. It can run at no other speed. See SYNCHRONOUS SPEED.

SYNCHRONOUS SPEED. The speed at which a synchronous elec-

trical machine must run. It is fixed by the relation:

$$\text{Speed (r.p.s.)} = \frac{\text{Frequency (cycles per sec.)}}{\text{Pairs of poles}}.$$

Thus if the frequency is 50 cycles per second a two-pole machine has a synchronous speed of 3000 r.p.m., for four poles the speed is 1500 r.p.m., and so on.

SYNCHROSCOPE. An electrical instrument used normally for synchronizing alternators. It indicates the phase difference between the two voltages with which it is supplied and is usually arranged to indicate the frequency difference as well. See SYNCHRONISM.

SYNTHESIS. The making of a compound from the elements composing it or from simpler compounds than can themselves be made from elements. Thus the manufacture of carbon disulphide, CS_2, from carbon and sulphur is a synthesis.

The synthesis of organic substances, i.e. compounds of carbon, is of great industrial importance. Synthesis is often hastened by the presence of a catalyst such as finely divided platinum or some other metal. Acetylene, C_2H_2, can be synthesized from carbon and hydrogen by heating them together to a high temperature; it can also be made by acting on calcium carbide, CaC_2, with water. From acetylene it is easy to synthesize ethylene, C_2H_4, alcohol, C_2H_5OH, and from the latter many substances. The synthesis of acetic acid, CH_3COOH, was effected by Kolbe in 1845. Benzene, phenol and naphthalene were synthesized by Bertholet in 1851 and subsequent years.

In 1856 the first aniline dyestuff was synthesized by Perkin, who heated aniline, $C_6H_5NH_2$, with sulphuric acid and potassium dichromate and so obtained the dyestuff mauve.

The synthesis of rubber-like materials is now an important industry, but none of them is exactly like rubber. In the Haber process for making ammonia, invented about 1913, one volume of nitrogen is mixed with three volumes of hydrogen. The mixture is compressed and passed at a temperature of 500 deg. C. over a catalyst consisting of iron and molybdenum. The nitrogen and hydrogen combine to make ammonia gas, NH_3, and from this nitric acid, HNO_3, is easily made, and many important explosives.

In 1906 and subsequent years Baekeland, a Belgian chemist who settled in America, studied the action of phenol, C_6H_5OH, on formaldehyde, HCHO, both of which had previously been made synthetically, and founded the industry of the Bakelite resins, of which Bakelite, Keebush and Tufnol are well-known examples.

SYNTHETIC PAINT AND VARNISH. Materials in which the oil content is replaced by an artificial substance possessing the characteristics of a natural resin.

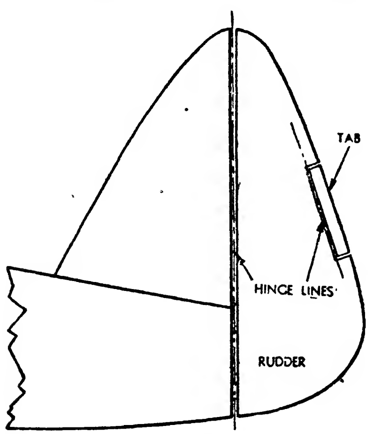
During the research undertaken to supplement the limited supply of natural resin available for varnish-making, it was found that the fusion of the various ingredients could be stopped when it reached a thick syrup-like stage. On dilution with turpentine and exposure to light and air as a thin film the rearrangement of its atomic structure continued until it was transformed into a solid.

This differs from the chemical change which takes place in the drying of linseed oil. All synthetic materials supplied as liquids for varnishing, or as liquids into which pigments have been ground for use as paint, are supplied ready for use; the addition of the ordinary paint driers will not accelerate drying but may upset the chemical balance and cause a premature breakdown of the film.

The ground to receive them must be clean, firm and slightly granulated; they should form the whole structure of the film, from priming coat to finish. Breakdowns occur through using a synthetic varnish upon an elastic ground which has dried owing to the oxidation of its oil content.

TAB (Aero. Engineering). A small hinged inset portion of a control surface, as shown in the accompanying illustration of a rudder. When the tab is rotated about its hinge the pressure generated on the side to which it has been moved, together with the suction on the other, produces a force which pushes the control surface over to the opposite direction.

Tabs have two uses: first, to reduce the hinge moment, and hence the operating load, of a control surface; and secondly, to bias a control surface over in either direction for trimming purposes. When a tab is geared to move with a control surface it reduces the hinge moment of the control surface and is known



Example of the use of a tab to assist the "trim" of an aircraft's control surfaces and to reduce the operating load for the pilot.

as a *geared* tab. Any desired amount of balance can be obtained by varying the tab size and gearing.

Unfortunately, when a control surface so balanced is fitted on high-speed aeroplanes, if it requires a reasonable force to operate it at high speeds, it becomes unpleasantly light at low speeds, or if correct at low speeds, it is far too heavy at high speeds. To overcome this undesirable feature a device called a spring tab has been invented; in this, by the arrangement of a spring in the system the exact required amount of tab bias is applied under all conditions to give reasonable operating loads.

A tab which is used for trimming purposes can be set at any desired angle by the pilot's cockpit control, and is unaffected by movement of the control surface. Some tabs are made to combine the duties of both balance and trim. See BALANCED CONTROL.

TACHOMETER, see REV. COUNTER.

TAIL SETTING. The angle at which the tailplane chord of an aircraft is set in relation to the chord line of the wing. It is desirable to have a tail setting so that in level flight, with the elevators neutral, the aeroplane is in trim. In practice the angle varies between 0 deg. and −5 deg., and is sometimes called Longitudinal Dihedral. See DIHEDRAL ANGLE.

TAILSTOCK. The movable head of a lathe. It can slide horizontally to and fro along the lathe-bed, and should be in true alignment with the headstock (q.v.). It has a ground, conical interior, to accommodate a hardened non-revolving centre, or poppet.

Final adjustment of position is made by means of a hand wheel mounted on the centre line. See CAPSTAN LATHE and LATHE.

TAIL VOLUME. A non-dimensional coefficient relating the horizontal tail area to the dimensions of the remainder of the aeroplane. Thus we have:

$$v = \frac{ls}{cS},$$

where v = tail volume; l = distance from the centre of gravity of the aeroplane to the centre of lift, or aerodynamic centre of the tail; s = area of horizontal tail; c = geometric

mean chord of the mainplane; and S = wing area.

The significance of the tail volume is that when mutiplied by the tailplane lift coefficient and the dynamic pressure, it gives the moment of the tail lift about the centre of gravity of the aeroplane.

At one time the tail volume was used directly to determine the tail area needed for a new design by assessing the required value of the coefficient from experience on earlier designs. Nowadays, when more is known about stability and control, we can calculate the tail area required by more precise means; the tail volume, however, is still a convenient coefficient to use in the computations.

TAIL WHEEL, see UNDERCARRIAGE.

TAKING-OFF, see BILL OF QUANTITIES.

TALC. A crystalline magnesium silicate, very similar to steatite, used as an insulator and as the chief constituent of certain toilet powders.

TALLOW WOOD, see EUCALYPTUS.

TANKING. A method often adopted when constructing buildings with basements, or multiple basement floors, to insulate the basement apartments from dampness. The tank is formed by incorporating a continuous lining of mastic asphalt within the thickness of the walls and the basement floor concrete, the walls forming the sides of the tank and the concrete floor the bottom. See SURFACE CONCRETE.

TANTALUM (Ta). Atomic no. 73; atomic wt. 181·5. A greyish metal resembling niobium, hard but capable of being drawn into wires. It can be alloyed with tungsten and molybdenum to make cutting tools. Density 16·6; m.p. 2800 deg. C.; b.p. 5500 deg. C. It is pentavalent and occasionally trivalent, forming such compounds as tantalum pentachloride, $TaCl_5$, and tantalum trichloride, $TaCl_3$.

TAP. A tool for cutting internal screw threads either by hand, or on a tapping machine. To allow for the removal of metal between threads (or to allow sufficient metal to remain after the tap has been run through, to form the thread) the initial hole must be drilled smaller than the outside (maximum) diameter over the screw threads. The size to which this hole is drilled is known as the tapping size; for Whitworth screw threads a hole for an outside thread diameter of ¾ in. has a tapping size of ⅝ in.

There are normally three taps—shown in Fig. 1—in each complete set for a given size. One, the *taper*

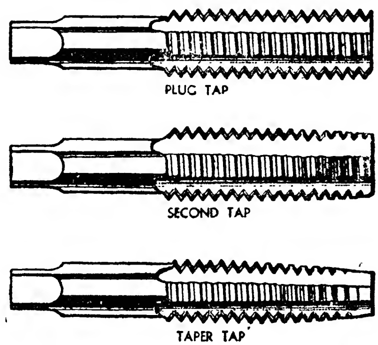


Fig. 1. In normal practice three taps, as shown above, are employed to cut any given size of thread required.

tap, is provided with a considerable amount of taper, to allow an easy start to be made in cutting and to ensure the correct positioning of the tap on the centre line of the hole. This is followed by a *second* tap having much less taper than the taper tap, 2 or 3 threads only being affected.

Finally a *plug* tap is supplied; this has full-diameter threads throughout, and is used chiefly to follow up the second tap when threading blind holes. Taps are rotated by means of tap wrenches; these may have either a single handle used like a spanner, or may consist of a round bar, with the ends shaped like handles and a square hole in the middle for the top. The latter type is preferable wherever it can be used, as it enables a more uniform pressure to be applied and reduces the danger of breaking the taps. Since taps are of necessity extremely hard, in order that they may have a long life, the danger of fracture is not remote, and care must

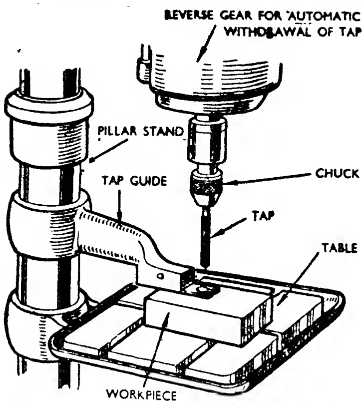


Fig. 2. Tapping machine for producing internal screw threads in large numbers. Tap is withdrawn automatically.

be exercised in their use, especially for small-diameter work.

For the production of tapped holes in large quantities, as in mass-production work, tapping machines are used; they work somewhat similarly to small vertical drilling machines (Fig. 2), but are provided with an automatic reversing device to cause the withdrawal of the tap.

TAP CHANGER. A piece of electrical equipment by means of which the voltage ratio of a transformer may be adjusted. It operates by altering the number of turns in circuit in one of the windings and may be of the off-load or of the on-load type.

The on-load variety is designed to operate while the transformer is energized, while the off-load type is operated only when the transformer is disconnected.

TAPER ROLLER BEARING, see BEARING.

TAPPING. A connexion to an intermediate point on an electrical component or circuit.

TARTARIC ACID ($C_4H_6O_6$). Occurs in three forms, one of which rotates polarized light to the right, one to the left; one is optically inactive. The commonest variety is *d*-tartaric acid, made from argol and wine lees. It is used in calico printing, baking powders and effervescing drinks. A fourth variety is a compound of the first two forms, called racemic acid.

TASMANIAN OAK, see EUCALYPTUS.

TAUTOMERISM, see ISOMERISM.

TEAK. Burma teak is an excellent wood for all purposes where strength, durability and appearance are required. It has great resistance to insects and to fire, and is hard, heavy, stable and strong. It is, however, difficult to work when seasoned, owing to the hardening of a secretion. Many other woods, with a distinguishing prefix, are called teak because they have some of its characteristics, but few are as satisfactory. See TIMBER.

TECHNICAL DRAWING. A method of illustrating which employs certain conventions in technical or engineering work and provides a language, or means of recording and exchanging information, down to the last detail, on the objects illustrated.

Unlike artistic drawings, nothing is left to the imagination; the effect of colour does not enter into the subject; and the views of the object are limited to outlines which do not present it as it would appear to the eye of an observer untrained in the conventions of engineering drawing.

This method of drawing aims at a mathematical accuracy of representation, which is achieved by the use of various instruments. When the fundamentals of the art are mastered, it should be possible for anyone having a knowledge of them to form a mental picture of the object illustrated.

There are certain small variations in style, which have grown up largely within certain fields, e.g. the peculiarities of architectural or structural steelwork drawings, as compared with those of the engineer. But in any case, a knowledge of the principles involved in such drawings is absolutely essential in the professional work of the engineer—civil, mechanical or electrical—and of the architect and builder and in allied professions.

INSTRUMENTS AND THEIR USES. The best instruments will be found well worth their higher cost, and for

general technical drawing the equipment needed includes a set of instruments in a case, comprising pencil and pen compasses with lengthening bar, dividers, spring-bow compasses (i.e. screw-adjusted), pens and ink; spring dividers, a drawing board, set squares (30 deg. and 45 deg.), a T-square, a 12-in. scale (civil engineer's or mechanical engineer's and architect's), a protractor and French curves. In addition, ruling pens will be needed as well as pencils, erasers and "artgum" or cleaning rubber.

The compasses should be about 6 in. in length, whilst the spring-bows should be about half that size. The drawing board should be made of cleated sections to obviate distortion due to warping, and should have a hardwood working edge. The T-square is used with the blade horizontal, *never vertical*, the head always being used in contact with the hardwood edge of the board. Set squares of transparent material are usually preferred to the wooden type.

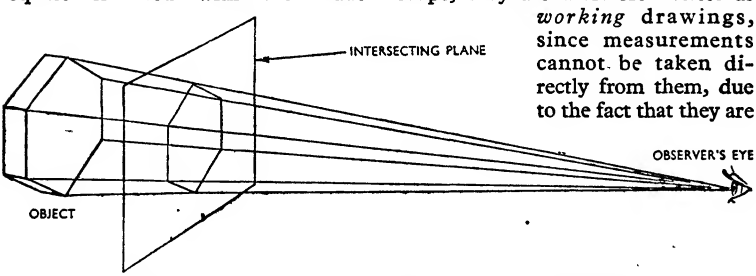
The scales are generally of boxwood; a favourite form is of triangular cross-section, so as to provide a greater number of scales than the flat variety. French curves are available in great variety, but one including the elliptical curves and one log (logarithmic) spiral are usually sufficient; they are used for drawing ellipses, spirals, cycloids and other non-circular curves.

A drafting machine is a device incorporating T-square, set squares, protractor and scales, clamped on to the edge of a drawing board which is usually held in an adjustable metal frame; it is much used in commercial drawing offices, where it is estimated to save a great deal of time, especially in structural drawing.

Projection: Orthographic. The use of planes of projection constitutes the fundamental difference between engineering drawing and artists' work. In the latter, the effect of perspective is admitted, and the "bundle" of rays of light from the observer's eye to points on the outline of the object viewed tapers uniformly from object to eye, so that the apparent size of the object will depend on its distance from the observer. This is illustrated diagrammatically in Fig. 1.

Perspective drawings thus show the object as it appears, and not its actual shape; they are therefore useless as *working* drawings, since measurements cannot be taken directly from them, due to the fact that they are not drawn to scale. Their only use in technical work is in certain classes of preliminary sketches in architectural design.

The amount of taper in the "bundle" of rays, as shown in Fig. 1, will be governed by the distance between object and observer. If this distance is infinitely great, the rays will become parallel, and the size of the object on *any* intersecting plane (if the plane is at right-angles to the rays) will be the same. The outline thus formed on such a plane in such conditions is termed orthographic projection. The width and height of the object will be shown, but not its depth; but this difficulty is overcome



EFFECT OF PERSPECTIVE ON ARTIST'S DRAWING

Fig. 1. Diagram shows how the distance of observer's eye affects the apparent size and shape of an object, unsuiting this type of drawing for accurate work.

by viewing the object from more than one direction.

Since all objects possess three dimensions in space, three planes are needed to represent the three-dimensional outlines of the object. It is the established custom to take these three planes as being mutually at right-angles. Even so, if the object is not symmetrical about its various centre lines, more than three views may be needed to describe it fully. In all such cases, though only three dimensions are still involved, it will be necessary to view the object both above and below, or from both front and back, or from both sides, as the case may be, to obtain all the details. In some cases, however, e.g. in drawing a square prism, only two views are needed, since the outline in the third plane is the same as that in the second.

In general, the front elevation should be the principal view, and for this reason the direction comprising the greatest single dimension should be chosen for the front view. Where there is a choice of side views, the one presenting the lesser number of hidden lines is preferable. The relative positions of the different views needed to furnish complete information about an object are shown in Fig. 2. This arrangement is the standard British practice.

It will be seen that if the object is arranged by the intersection of the three planes of reference A, B and C (which are mutually at right-angles), the view obtained when looking in the direction of arrow *a* goes on plane A. This is termed "projection on to plane A". Similarly the views obtained when looking in the direction of arrows *b* and *c* go on planes B and C respectively.

If the object is not symmetrical about one of its centre lines, then a fourth plane, e.g. D, may be needed, on which to project the view obtained

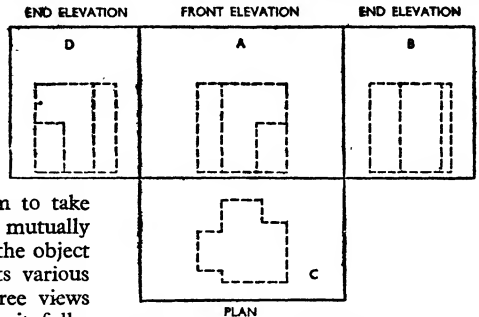
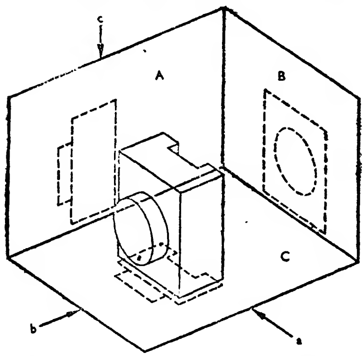
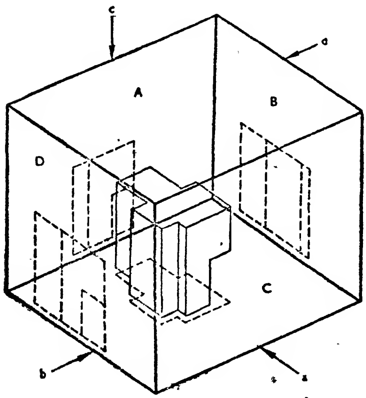


Fig. 4. Example above gives the normal British practice for arranging a set of working drawings where it is necessary to show plan and elevations.



Depicted here are two simple examples of generally recognized British practice in preparing technical drawings. Fig. 2, above, illustrates the established arrangement of planes of reference for a three-dimensional view. Fig. 3, below, shows how a fourth plane may be utilized so that full working data shall be furnished in the case of a non-symmetrical object.



when looking in direction *d* as shown in Fig. 3.

Now imagine these various planes to be hinged wherever they meet, so that they can be opened and spread out on a flat surface. If this is done, as shown in Fig. 4, we get all the views in their appropriate relative positions. This gives, in effect, a set of working drawings for the simple object illustrated, consisting of front elevation, plan and two end elevations.

In Canada and the U.S.A. there is one important difference in these conventions. The two end elevations shown in Fig. 4 would appear transposed, whilst plan and front elevation maintained the same relative positions. In other words, the view obtained when looking in direction *b* in Fig. 3 would be projected on to plane D, and not on to plane B; similarly the view obtained from direction *d* would be projected on to plane B, and not on to plane D.

Isometric Projection. We have seen that a perspective drawing, while it presents an object as it appears to the eye (in contrast to orthographic projection, which is based on the dimensions as they really are) is useless as a working drawing, since its lines cannot be measured directly. A useful compromise between orthographic projection and the perspective view is obtained by drawing the object to a system known as isometric projection.

In this method, it is possible to set out the principal lines to direct measurements with a scale. Only one view is normally needed in this one-plane system, which seeks to present the object in such a way that its true dimensions are shown in two fixed directions, whilst the third dimension is *represented* (but not to the same scale) by ensuring that three faces of the object are visible. Patent specifications, illustrations for the technical press etc., often lend themselves to representation by this system.

Another advantage of isometric projection is that, once learnt, it is very useful for making rapid freehand sketches of objects, since it virtually enables the information which would normally need three or four views in orthographic projection to be combined into a single sketch.

An isometric view of a cube with a circle inscribed on each of its faces is shown in Fig. 5. The circle

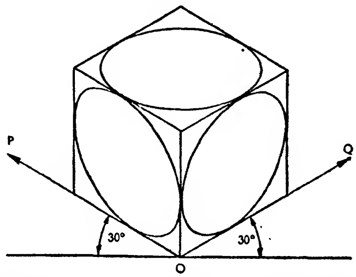


Fig. 5. Isometric projection of a cube with a circle inscribed on each face.

diameter is equal to the width of the faces, and the circumference thus touches each of the four edges. The principal axes OP, OQ are set out, making 30 deg. with the horizontal, and true dimensions may be scaled off *only along those axes*, or along lines parallel with them. In no other directions will true dimensions appear. It will be seen that circles in orthographic projection become ellipses in isometric projection.

There are several variations of this principle of projection, including oblique projection, but the foregoing is most often used.

First Angle Projection. In order to secure uniformity in drawing office practice, the British Standards Institution, in their Specification No. 308, 1927, recommend that the 1st Angle Projection should be adopted as the standard. The distinctive feature of 1st Angle Projection is that each view appears on the side of the object remote from the face that it portrays, i.e. a top view or plan is placed beneath the elevation, an end view looking from right of object is shown on the left, as Fig. 6 overleaf.

Centre Lines, Dimensions etc. In preparing a set of working drawings showing the different views of an object in orthographic projection

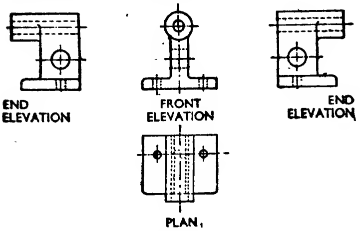


Fig. 6. First angle projection, showing how elevations and plan are set out.

rough estimates of the amounts of space needed for the front and end elevations and plan are first made, so that the general layout on the drawing paper may be decided upon at the outset. Next the centre lines are drawn and these constitute the axes for every symmetrical portion.

Every circular or cylindrical portion should have its centre line drawn first, and all circles (and in many cases circular arcs) should have their centres shown as the point of intersection of a vertical and horizontal centre line. The conventional way of showing centre lines is a series of alternating long and short dashes. Centre lines should always be brought beyond the boundary lines of the figure; they are very important as each forms a datum line from which other measurements are made, and from which dimensions are marked. Hidden lines and surfaces are represented by dotted lines.

Dimensions should never be marked on the actual boundary lines of the object to which they refer, but should be brought outside and inserted within a suitable gap left in a supplementary line, known as a dimension line, drawn parallel to the boundary line concerned and connected to it by short perpendiculars at each end.

An item too large or too long to be accommodated on the sheet, e.g. a long shaft, may be shown "broken", i.e. with a portion omitted, provided that no dimensions are omitted by doing so. Surfaces produced by cross-sections are usually shaded by section lining, the direction being at 45 deg. to the centre lines. If two different parts form adjacent surfaces on a cross-section, the section lines are usually reversed in direction, to help in distinguishing the component parts.

Working drawings should comprise the full set of views of the object to be shown, with dimension lines and dimensions, a descriptive title and reference letter (if needed), and any necessary requirements in manufacturing processes, e.g. heat treatment, surface finish etc. Drawings themselves may be either assembly drawings or detail drawings.

The term design drawing is sometimes given to the original assembly drawing forming the preliminary layout on which the actual calculations and building-up of the product are carried out, and from which the detail drawings are prepared.

TRACING. In the works drawing office, the pencil drawings prepared by the draughtsman are traced on specially prepared transparent linen or thin tracing paper; the medium is waterproof black Indian ink; the tracing linen or paper is securely pinned over the drawing and the surface of the linen or paper is dusted with French chalk to neutralize the greasy surface, so that the ink will run freely.

Tracing is a specialized craft and in most drawing offices girls are trained in the work; the rules of drawing practice prevail, however, and the finished tracing should not only be an accurate copy of the drawing, but must have a high degree of orderliness.

No drawing is of use to the workman if it is not clear or if all dimensions and instructions are not legible. The fractional portion of dimensions, particularly, should be made bold; the oval portions of numerals should be open and full, otherwise there may be confusion on account of the similarity of, for instance, 3 and 5 or 3 and 8.

In practice, the height of the numerator and denominator should be two thirds the height of the integer and a single horizontal line or

bar should separate the numerator and denominator.

Good balance in lettering demands that the area of the white space between adjacent letters should be approximately equal and, further, the white areas between successive words must appear the same.

COPYING PROCESSES. The object of tracing drawings on to linen is two-fold, first to make a permanent record and, secondly, in order that copies may be made of the tracing by means of one of the many copying processes where the print appears either as white lines on a blue background or black, brown or blue lines on a white background.

Photoprints are made by placing the tracing on sensitized paper or cloth and exposing them for a definite period to sunlight or electric light on a printing frame or machine; in the making of blue prints, the sensitized paper after exposure is washed in running water, then dried; whereas in some of the later processes, where copies are made consisting of black or blue lines on white background, the exposed paper is developed in the dry condition, thus obviating troubles due to shrinkage and distortion of the prints.

TEE-CONNEXION. A method of connecting a two-phase winding of an electrical machine to a three-phase circuit. For a diagram of connexions see SCOTT SYSTEM.

TELEGRAPHY. An electrical system of communication wherein messages are conveyed in the form of interrupted currents or currents of varying frequency or amplitude.

TELEPHONE. An electrical system wherein sound waves are converted into electrical charges, transmitted in that form, and reconverted to sound waves at the receiving end. See LOUDSPEAKER, MICROPHONE and TELEPHONE RECEIVERS.

TELEPHONE RECEIVERS. Devices for converting electrical energy into sound energy. They generally comprise two separate earpieces attached to a headband and are provided with a flexible connecting cord. Two main types of headphone are in general use, the *magnetic* type and the *crystal* type.

In the double-pole magnetic type (Fig. 1), the signal current is passed through a pair of coils which are wound on suitable bobbins and surround the pole pieces of a permanent magnet. The diaphragm is a thin disk of soft iron close to the open ends of the magnet and is securely

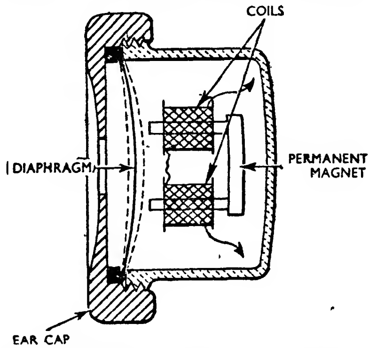


Fig. 1. Sectional view of magnetic earpiece of telephone receiver. Dotted lines show how diaphragm moves in response to an alternating current flowing through the coils.

clamped at its outer edge by the ear cap. Its centre is drawn towards the pole pieces by the influence of the magnet.

When alternating speech currents pass through the windings, the field set up alternately aids and opposes the fixed field of the permanent magnet, and thus the diaphragm is either drawn nearer to, or allowed to spring farther away from, the pole pieces. The movement of the diaphragm sets up corresponding air vibrations which are heard as sound.

The D.C. resistance of the coils is usually either of the order of 2000 ohms (corresponding to an impedance of some 15,000 ohms at 800 cycles per second) or about 100 ohms, with impedance in proportion. The high-resistance type may be connected directly in the anode circuit of a small power-amplifying valve, but it should be remembered that the current limit is only a few milliamperes. The

low-resistance type will require a matching transformer.

The moving-coil earpiece is also of the magnetic type. Its operating principle is similar to that of the moving-coil loudspeaker but certain constructional details and physical dimensions are, of necessity, different. The impedance of such headphones

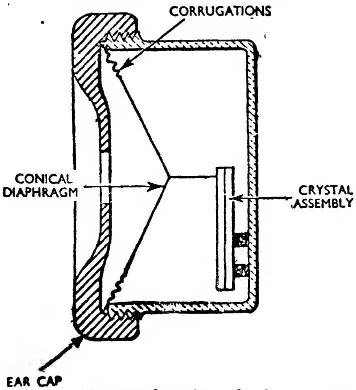


Fig. 2. Basic details of the crystal earpiece. Conical diaphragm has corrugated edges to allow movement.

is almost invariably low and thus they must be matched to an amplifying valve by means of a suitable transformer.

In the crystal type of headphone, two piezo-electric crystals of Rochelle salt are cemented together in such a manner that the pair will bend in one direction for an applied voltage of a certain polarity, and in the other direction when the polarity is reversed. The crystal assembly is so mounted on the inside of the earpiece that one end is clamped and the other end is attached to the centre of a flexible diaphragm (Fig. 2).

The application of an alternating voltage causes the free end of the crystal assembly, and hence the diaphragm, to vibrate to and fro, thus producing sound. Crystal headphones are of high impedance and can be used only on A.C.; they have no D.C. continuity, and a direct voltage will damage the crystals. They must be connected to an amplifying valve through a suitable isolating device such as a transformer or a condenser. See LOUDSPEAKER and MICROPHONE.

TELEVISION. The transmission by wire or radio of images and scenes for instantaneous reproduction at a distance by means of suitable receiving apparatus; in other words, visual broadcasting.

In 1880 Carey, an American, published details of apparatus designed to achieve television by imitating the human eye. It was realized, however, that to accomplish practical television it was necessary (1) to reduce the scene to a flat optical image, (2) to split this image into a large number of small parts, (3) to take each part (picture element) in order and derive from it a current or voltage proportional to its relative brightness, (4) to transmit a succession of these electrical impulses in a regular pre-arranged order, (5) to convert, at the receiver, these impulses into corresponding degrees of illumination again in the same order and (6) to repeat the entire process at least sixteen times a second. The method of reducing a scene to a flat optical image was already well known and is easily accomplished by means of suitable lenses.

In 1884, Nipkow suggested a television system (Fig. 1) in which

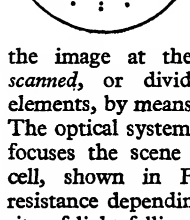


Fig. 1. Nipkow disk, pierced near periphery by small holes. One is near edge and rest are progressively nearer to the centre.

the image at the transmitter was *scanned*, or divided into separate elements, by means of a rotating disk. The optical system at the transmitter focuses the scene on to a selenium cell, shown in Fig. 2, the cell's resistance depending upon the intensity of light falling on it. The disk is interposed in the path of light from the scene to the cell and cuts off all light from it except that corresponding

to the small part of the scene opposite a hole at any particular instant. As the disk rotates, the current from the battery will flow in impulses proportional to the illumination of those parts of the scene being scanned.

At the receiver, another disk rotating in synchronism with that at

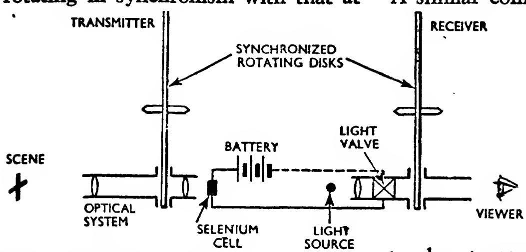


Fig. 2. Simplified diagram which illustrates the system of television suggested by Nipkow in 1884.

the transmitter, is placed as is also shown in Fig. 2. The light, from a source, is modulated by the received impulses and thus a viewer will see built up again an image corresponding to the original scene. This original system was not further developed until the introduction early this century of the thermionic valve.

The mechanical method of scanning is limited, first of all, in definition. To secure fine detail, a picture must be split into extremely small elements, and this could be accomplished only by a disk containing a large number of very small holes accurately located so that their traces adjoin but neither overlap nor leave a gap. Secondly, it is not easy to keep the disk turning at a constant speed of, say, even sixteen revolutions a second without encountering speed variation or vibration; nor is it simple to maintain synchronism between transmitter and receiver disks. Thirdly, there is the electrical difficulty that, as each point of the image is of minute size and falls on the light-sensitive cell for only a brief instant, an extremely small response is obtainable even if the scene itself is intensely illuminated.

In 1907, Rhümer constructed a transmitter in Berlin using a mosaic of selenium cells and a corresponding bank of lamps as a receiver, but the arrangement was necessarily clumsy and not practical. A somewhat similar scheme, due to Ayrton-Perry, sought to connect each selenium element in turn, using a rotary switch. A similar commutating device at the receiver connected a series of lamps in the correct order.

Other attempts at scanning were made, and included those in Paris by Bélin, who used oscillating mirrors to direct a beam of light over the scene to be transmitted, and those in America by Jenkins, who suggested glass disks ground at the edge as a series of prisms to zig-zag light over the object. Later, however, it was found that certain metals, such as sodium, potassium and caesium, were capable of emitting electrons under the action of light, and devices known as "photo-electric cells" were produced which were far more sensitive than selenium.

In 1908, Campbell Swinton proposed a television system using cathode-ray tubes both for transmission and reception, but made no practical use of it. Before it was revived, J. L. Baird developed a technique using a Nipkow disk, and in 1923 he was able to produce crude pictures. On January 22nd, 1926, he gave a demonstration to members of the Royal Institution, when a human face was transmitted. For this he employed a scanning disk which carried two spirals of lenses and the light reflected from the illuminated object was caused to affect a photo-electric cell. The apparatus then used is at the Science Museum, South Kensington, London.

During 1927 and 1928 a little progress was made in America by the American Telegraph and Telephone Co., and the General Electric Co., both using the disk method, while in England, Baird invented, in 1928, a rudimentary system of television in

colour and stereoscopic relief. On September 30th, 1929, the B.B.C. in conjunction with the Baird Television Company started an experimental public television broadcast service using the equivalent of a 30-aperture disk. The definition, however, was scarcely sufficient to provide entertainment and, as the novelty wore off, the service was discontinued.

Electronic Method

Obstacles inherent in the mechanical systems led experimenters to seek a purely electronic method of scanning, and the development of the cathode-ray tube finally produced the "electron camera". The Farnsworth image-dissector and the Zworykin Iconoscope (q.v.) are results of intensive research on these lines. In order to obtain a picture having reasonable definition and freedom from flicker, it is necessary to transmit not less than some 200,000 separate impulses in one twentieth part of a second, representing a signal voltage which varies some millions of times a second. For such a frequency successfully to modulate a radio carrier wave, a transmission frequency would need to be extremely high and it was not until fairly recently, when ultra-high frequency technique was better understood, that high-definition television by radio was possible.

A system of high-definition television transmission developed by E.M.I., Ltd., was adopted by the B.B.C., after trials and tests in which the public took part, and a transmitter was installed at Alexandra Palace in 1936. The scene to be televised was focused on to the mosaic screen of an Iconoscope, where it was scanned by an electron beam in a succession of horizontal sweeps, each one vertically displaced from the one before it. The image, which had a horizontal-to-vertical ratio of 5 to 4, was, by this means, divided into 405 "slices", or lines, representing over 200,000 picture elements.

To scan the complete picture, or "frame", 50 times a second would have meant unnecessarily high-frequency picture impulses, while a 25-cycle frame frequency might have given rise to objectionable flicker. This difficulty was overcome in an ingenious manner. The image was not scanned in consecutive lines but by taking every other one in one twenty-fifth of a second and by dealing with those omitted by another scan in the next one twenty-fifth of a second. Thus, due to the persistence of vision and of fluorescence at the receiver, a definition represented by 405 lines was maintained while the flicker frequency was 50 cycles per second and could not be detected. In other words, 202½ lines were covered in the first frame scan, and the other 202½ lines in the second scan, and so on. The system is known as *interlaced* scanning.

In order that the time bases in the receiver shall keep in exact step with those at the transmitter, synchronizing pulses are radiated, one at the end of each line and another at the completion of each frame. Line-synchronizing pulses are relatively short, whilst frame pulses are longer and, by means of a suitable separator circuit, the receiver is able to discriminate, feeding the correct pulses to the appropriate time bases.

The transmitter is *power modulated*, 30 per cent aerial power representing picture black, and 100 per cent power, full white. The synchronizing pulses correspond to a drop in aerial power from 30 per cent to zero and thus, being "blacker than black", are not seen on the reproduced picture. The vision transmitter carrier-frequency is 45 Mc/s, and the accompanying sound is radiated by completely separate equipment operating at 41·5 Mc/s.

A suitable television receiver follows normal practice, except that the tuned circuits are unusually broad so as to accommodate the necessary band width. The rectified output is applied to the modulating electrode of a cathode-ray tube whose beam is deflected horizontally and vertically by suitably synchronized

time bases. The variations of applied voltage modulate the beam, so changing the intensity of fluorescence as the "spot" traverses the screen. In this way, a picture representing the original scene is built up.

It is interesting to note that it is due only to presistence of vision and of fluorescence that a complete picture appears; it is actually nothing more than a *minute spot* traversing the screen in a pre-arranged order, varying its intensity as it does so.

Other systems of television have been developed and some of the outstanding achievements are worthy of note. It is well known that the brightness of fluorescence in a cathode-ray tube depends not only on electrode potentials but also on the velocity at which the spot traverses the screen. An invention largely due to Puckle and Bedford utilizes this property for producing the necessary light and shade. The system, with its own special transmitter and receiver, is known as velocity modulation. In the field of large screen receivers, the Scophony Co. have been successful with electro-mechanical arrangements using the B.B.C. transmissions.

Various systems of television in colour have given good results—at least under laboratory conditions.

TELLURIUM (Te). Atomic no. 52; atomic wt. 127·5. An element chemically similar to sulphur and selenium, but with some of the properties of a metal. Density about 6; m.p. 452 deg. C.; b.p. 1390 deg. C. If alloyed in small proportion with lead, it toughens the lead. It is tetravalent and divalent, but its compounds are not important.

TEMPER. A term having a variety of meanings in metallurgy. It may denote: (a) the hardness of a tool after it has been heat treated: described as hard, full, medium, mild etc.; (*b*) the excellence or otherwise of a tool, e.g. poor temper, finest temper etc.; (*c*) the suitability of a tool steel for a particular duty and, indirectly, its carbon content—thus razor temper indicates carbon tool-steel containing about 1·4 per cent of carbon; die temper, 0·75 per cent of carbon and so on; (*d*) the process of reheating, at a comparatively low temperature, a tool previously quenched from a higher temperature, e.g. temper at 300 deg. C.

TEMPERATURE COEFFICIENT. The rate at which some physical property of a substance or body changes with temperature, expressed as a fraction or percentage of the value at a standard temperature. For example, the temperature coefficient of resistivity for copper is 0·004 per deg. C. at 0 deg. C. This means that for every Centigrade degree rise in temperature the resistance of a piece of copper increases by 0·4 per cent of its resistance at 0 deg. C.

TEMPERING. Heating a metal to a temperature below its critical range with the object of modifying properties obtained by previous heat-treatment. Thus, one per cent carbon-steel, after quenching in water from 780 deg. C., is extremely hard and brittle. Tempering at between 200 and 300 deg. C. results in a slight loss of hardness, which is more than compensated for by the great increase in toughness obtained.

The term was formerly used to indicate the whole process of heat-treating steel including both hardening and tempering, but its use in this connexion is rapidly being abandoned.

TEMPERING COLOURS. The series of colours through which previously heated steel passes on cooling, which form a guide to the temperature at which it should be quenched. Steel used for lathe and other cutting tools, chisels, drills, scrapers etc., must be capable of being hardened, to ensure a reasonable life for the cutting edge. The hardness will depend upon the degree to which the tool has been heated and on the temperature at which it is subsequently quenched. A useful rough guide to the operation is available in the tempering colours which become visible when a piece of tool steel or chisel is heated. The bright metallic surface, on heating,

Temper Colour	Temperature Deg. F.	Tools
Pale yellow	430	Cutting tools for lathes, shapers, planers etc. Milling cutters, drills, reamers. Taps and dies.
Light straw	450	
Dark straw	470	
Brown	490	
Brown, purple-speckled ..	510	Centre punches and cold chisels. Screwdrivers.
Purple	530	
Bright blue..	560	
Dark blue	600	

first takes on a yellowish colour (due to a surface film of oxide), and passes through various shades as the film of oxide thickens, until a dark blue is reached.

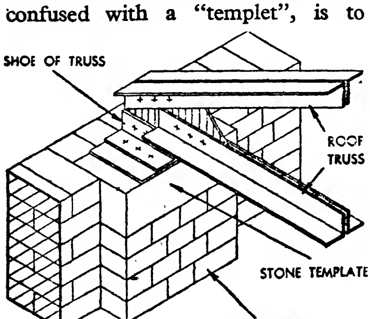
The actual shades correspond to different temperatures, as shown in the table above.

The appearance of one or other of these colours is an indication of the extent of reheating, i.e. the degree to which the temper has been "drawn". Thus the piece drawn to a blue colour is much easier to file than that drawn to a straw colour.

The presence in a tool of a temper colour does not necessarily mean that the tool has been hardened, for both hard and soft articles will exhibit the same colours.

TEMPER MILL, see Skin-Pass Mill.

TEMPLATE. A block of stone or concrete bedded on a wall to act as a seating for the support of a beam. The function of the template, often confused with a "templet", is to receive the load from the beam and distribute it over a large area of the wall.



How template is used to distribute load from beam over section of wall.

TEMPORARY TIMBERING. Work which acts as a support during construction, known as timbering, centring, shoring, scaffolding, piling, and shuttering or form-work. Timbering is used in excavations to support the sides, and sometimes the top, while the brickwork etc. is built, and depends for its type upon the depth of the excavation and condition of the soil.

Shallow trenches in hard ground, for example, require only occasional poling boards and struts, but if the ground is waterlogged or loose, close boarding is necessary, and the sides should be inclined a little so that the timbering will tighten in case of movement. It is better to err on the safe side, as a collapse entails a lot of labour in making good, and may be dangerous.

Deep trenches require timbering as in the illustration overleaf, which indicates two throws of 5ft. 6 in. each. This is the usual depth for each set of poling boards, irrespective of the depth of the trench, and represents the limit a man can throw the excavated earth. In deeper trenches platforms are built, on to which the earth is thrown. Wedges may be used between waling and poling boards to tighten the boards against the earth face; alternatively, folding wedges may be used at the ends of the struts.

Deep-site excavations require shoring, as explained later, but trenches may be run round the site, and timbered as shown until the

walls are erected to a reasonable height. The interior mound of earth, called a dumpling, can then be removed.

CENTRES are temporary frames to support the voussoirs, or stones, of an arch until the arch is erected. Centres may vary from a single piece, called a *turning piece,* to very elaborate engineering structures for bridges.

The illustration also shows a simple example for a semicircular arch applied to vaulting, but the same centres would serve for an arch in a wall. The shape of the rim, or felloe, depends upon the outline of the arch, which may be circular, elliptical, parabolic etc., but the framework and construction of the centre depends upon the span and the weight thrown on it during the turning of the arch. Centres may be framed like a roof truss for large spans, but economy must be considered when designing the centre. The work is temporary and the timbers should be cut up as little as possible to enable them to be utilized subsequently for other work.

For a continuous arch, such as a bridge or vaulting, a number of ribs are required as shown, but for an arch in a wall, only two are required to carry the laggings, or supports. Close lagging is used for gauged brickwork and open lagging for ordinary brickwork. Two lags to each voussoir, or stones forming the arch, are required for masonry. The centres are supported on props and folding wedges. Two props, connected by a bearer for the wedges, are usually required on each side for an arch. When the arch is completed the wedges are eased, or slackened, to allow the arch to bed into position. The centres are struck, or removed, at a later date if no defects have developed when the mortar has hardened.

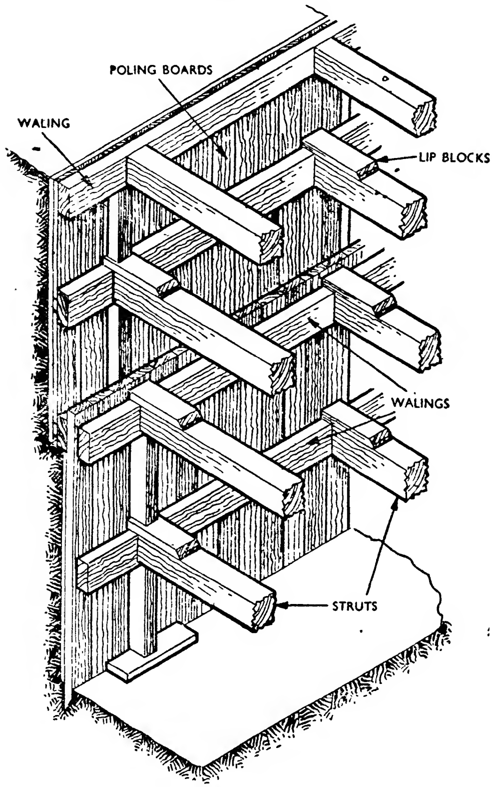
SHORING may be simply a wood prop or it may be a massive system of heavy timbers. The various methods are known as raking, flying, or dead shoring; they are used for supporting defective buildings, or those undergoing structural alterations, or for supporting the sides of large excavations. *Raking Shores* are inclined struts, and the system may consist of a single raker or a series of rakers as shown.

The shores are intended to take the thrust from the floors and roof of the building, and the axis of the shore should meet the centre line of the wall plate supporting the floor joists or rafters. The example shows a wall-piece, 3 in. thick × 9 in. wide, supported on needles projecting into the wall, and secured to the wall by holdfasts or spikes. *Flying* shores are systems of shores having no support from the ground. They can be used only where an adjacent building is at a convenient distance away, up to 40 feet. A *single* shore may be used, or a braced frame of one or more tiers may be required, as shown for a four-storied building. *Dead* shores are vertical posts for supporting dead loads only, and not subjected to any inclined thrust. A common example consists of dead shores on each side of a brick wall and supporting a needle passing through the wall to take the weight of the brickwork above. In this case the dead shores and needle are heavy timbers about 9 in. × 9 in. to 12 in. × 12 in.

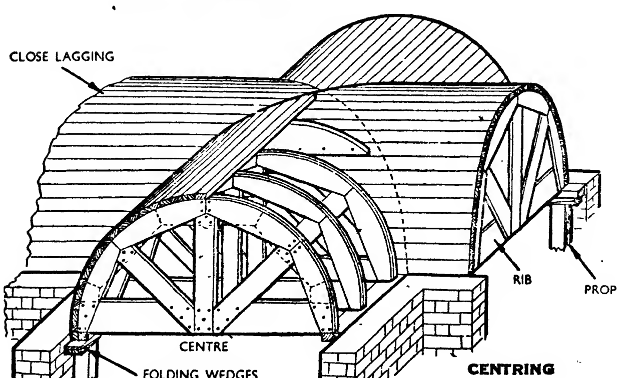
Types of Scaffolding

SCAFFOLDING is a temporary stage, or platform, for carrying men and materials during the erection of a building etc. There are many different types, distinguished according to their particular function: bricklayers', cradle, derrick, flying, gantry, independent, masons', saddle, suspended, travelling etc. Timber scaffolding is giving place to tubular steel for the structural part. The numerous patents applied to the connexions of the latter allow for speedy erection, and afford greater measure of safety than with the ropes used with pole scaffolding.

PILING, which may be temporary or permanent, is a system of timbers driven into poor bearing soils to carry the superincumbent loads. When



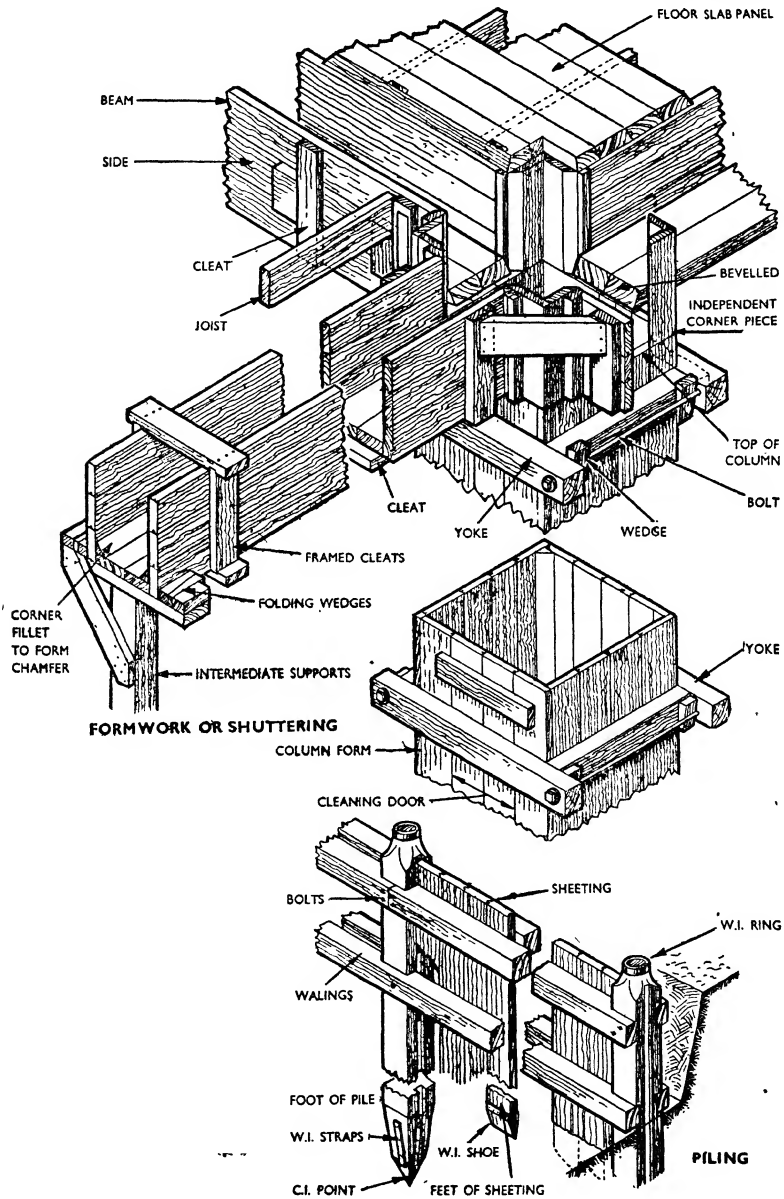
TRENCH TIMBERING



CENTRING

STRUCTURAL DETAILS OF

Indicated above are some essential constructional features of the different forms of woodwork set up as a support during the erection of structures in brick, stone and similar materials, and to retain in place the sides and top of



TEMPORARY TIMBERING

excavations. The drawings are intended to illustrate only the principles of each kind of timbering. Many applications are mentioned in the article on the preceding and following pages. On any job, several timbering processes may be involved.

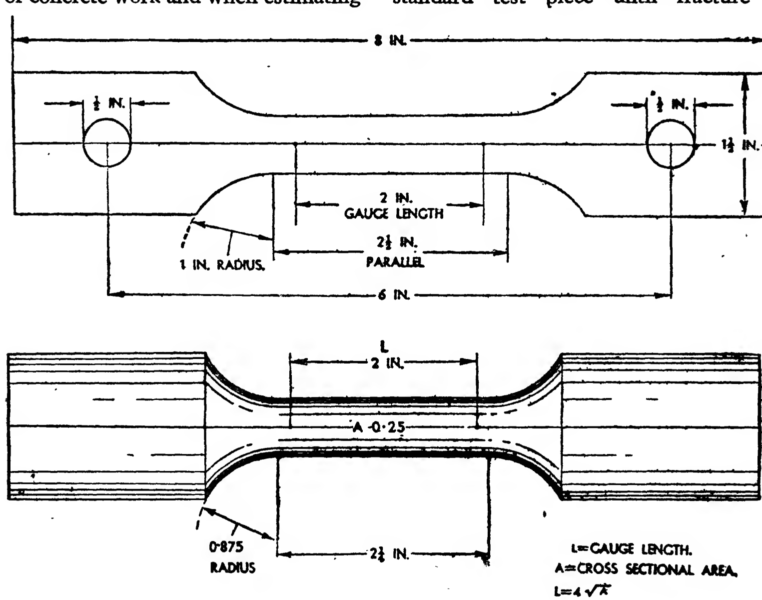
permanent, however, the piles are usually of concrete. Close piling is used to encircle a water-logged site so that the site can be drained when the piling is completed. It is also used for under-water work; in this case there are two concentric rings with puddled clay between, to keep out water while the work is proceeding inside.

On modern work it is customary to use patent metal sheeting. The example shows the arrangement of timbers for both piles and wood sheeting, the latter being from 2 in. to 3 in. thick, according to requirements, while the piles and walings vary accordingly. The timbers are driven by a pile driver, which may be operated by hand or power.

SHUTTERING, known variously as formwork (q.v.), sheeting and falsework, is used as temporary support during the casting of concrete. The correct design and erection of shuttering are very important for the strength of concrete work and when estimating its cost. In the interests of economy it must also be designed for easy striking (removing) and for future use. The illustration shows the formwork required for column, beam and floor in a reinforced concrete building. The yokes to the column are necessary because of the pressure of the wet concrete.

The surface of the concrete depends upon the condition of the face of the shuttering, and sometimes linings of hardboard are used to provide a good surface to the concrete. Shutter oil etc. is used to allow for easy striking, and to prevent absorption of the water from the concrete. The formwork for any kind of concrete casting must be rigid and securely fixed, as any appreciable movement, once the concrete is poured, may seriously damage the concrete. See FORMWORK, SHORING and TIMBER CENTRES.

TENSILE TEST. A test, used in metallurgy, in which a gradually increasing axial pull is applied to a standard test piece until fracture



TYPICAL STANDARD TENSILE TEST PIECES

Fig. 1. Form and dimensions suitable for normal tests carried out on cast or bar material to obtain important data on the behaviour of the metal under stress.

occurs. Important data obtained from such a test include the maximum stress or ultimate tensile stress; yield point (steels); proof stress (non-ferrous materials); elongation per cent and reduction of area per cent.

Standard tensile test pieces are shown in Fig. 1, opposite. Testing is

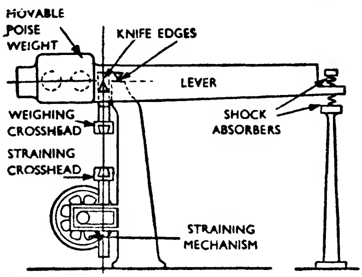


Fig. 2. Single-lever type of machine, electrically driven, which transmits a given load through a specimen submitted for standard tensile tests.

done in special machines capable of exerting loads up to 100 tons, 30- or 50-ton machines being most common. These machines are either of the lever type or the load is applied and measured hydraulically.

In the single-lever type illustrated in Fig. 2 an electrically driven straining mechanism is used. The load is transmitted through the specimen to the weighing apparatus, which consists of a beam with a movable counterpoise weight. Compound-lever machines enable increased capacity to be maintained, while keeping the size and area occupied by the machine within reasonable limits.

Brittle materials such as cast-iron break without any appreciable stretching in this test. Ductile materials, however, stretch elastically up to the yield point (q.v.), and from this point onwards the test piece stretches visibly until the maximum load is reached, at which necking (q.v.) takes place. Further stretching may then occur without any increase, and even sometimes with a slight reduction, of load.

The elongation thus produced is measured over a standard gauge-length scribed on the test piece, and is calculated as a percentage of the original gauge length.

With some materials no definite yield point can be observed, in which case the proof stress is measured. With light alloys, which do not show a yield point, the 0·1 per cent proof stress is taken, i.e. the stress which produces a permanent extension not exceeding 0·1 per cent of the original gauge length.

Summary of Tensile Test Results.

Maximum stress (tons per sq. in.)
$$\frac{\text{Maximum load (tons)}}{\text{Original cross-sectional area}}$$

Yield point
$$\frac{\text{Yield load (tons)}}{\text{Original cross-sectional area}}$$

Elongation (per cent)
$$\frac{\text{Increase in length}}{\text{Original gauge length}} \times \frac{100}{1}$$

Reduction of area (per cent)
$$\frac{\text{Reduction in cross section}}{\text{Original cross section}} \times \frac{100}{1}$$

See ELONGATION and PROOF STRESS.

TENSION (Building), see STRESS.

TENSIONER WHEEL, see IDLE WHEEL.

TERBIUM (Tb). Atomic no. 65; atomic wt. 159·2. A rare-earth element that has not yet been isolated; it forms oxides, Tb_2O_3 and Tb_4O_7.

TEREBINE. An extremely dilute form of liquid drier for use with oil paint; any instruction supplied by the manufacturer as to its employment must be strictly observed. Used in excess of minimum requirements it is liable to cause a friable paint film.

TERMINAL VELOCITY. The maximum speed an aeroplane can attain when descending in a vertical nose dive. Under these conditions the wings are producing no lift, the gravitational forces, plus any thrust exerted by the propeller if the engine is running, being exactly balanced by the drag. Terminal velocities range from under 200 m.p.h. for high-drag biplanes, to about 600 m.p.h. for good, low-drag fighter aircraft.

TERNE PLATES. Steel sheets coated with an alloy of lead and tin. The name derives from the French *terne* (dull), the coating being very much less brilliant than that of tinplate. Terne plate is used for roofing, for

road-vehicle petrol tanks, and in general for making containers and vessels for carrying and handling non-food products.

The composition of the alloy used for coating varies from 2 to 50 per cent of tin, the balance being lead. Common ternes usually carry a coating containing from 10 to 12 per cent of tin, whilst tin ternes carry a coating containing from 20 to 25 per cent of tin.

The term *lead-coated iron* is sometimes used to describe material coated with an alloy of lead containing only small quantities of tin, e.g., 2 to 3 per cent.

Long ternes are sheets up to a size of 12 ft. × 4 ft. and up to 10 gauge in thickness. *Short* ternes are rectangular sheets, about 28 in. × 20 in. and of about 30 gauge.

TERPENES. Volatile aromatic hydrocarbons with the formula $C_{10}H_{16}$. They may be regarded as polymers of isoprene, C_5H_8, which is formed when rubber is heated. The terpenes are important components of many vegetable oils, and are largely used in perfumery.

TERRA-COTTA. A clay product that will vitrify and resemble stoneware. A variety of clays are mixed and blended together in suitable combination, so as to obtain the proper texture and colour, kneaded with the aid of water and then modelled by hand or, alternatively, moulded to shape in the form of hollow blocks. When partly dry, the clay is turned out on to a platform, touched-up to suit the required details, dried in special driers and afterwards baked in a kiln.

The dimensions of terra-cotta blocks are limited because of the contraction and warping of the material during burning processes. In construction processes, the spaces in the blocks may be filled with fine concrete.

TERTIARY WINDING. A third winding on an electrical transformer, in addition to the primary and secondary. It may be used to supply a second circuit or to reduce the effects of triple harmonics. See PRIMARY WINDING and SECONDARY WINDING.

TETRAVALENT, see VALENCY.

TETRODE. A four-electrode radio valve also known as a screened-grid valve, having two grids as well as cathode and anode. The grid nearer the cathode is the normal control electrode, the remoter one usually functioning as a screen. See RADIO VALVE.

THALLIUM (Tl). Atomic no. 81; atomic wt. 204·39. A substance widely distributed in small quantities in many minerals; it may be obtained from flue dust in the manufacture of sulphuric acid from some varieties of iron pyrites. It is a soft metal resembling lead, density 11·85, m.p. 302 deg. C., b.p. 1462 deg. C., and is usually monovalent. Thallium acetate, $CH_3.COOTl$, is used medicinally as a cure for ringworm.

THERM. The unit of calorific value by which coal gas is sold to the consumer. It is 100,000 British Thermal Units (q.v.).

THERMAL CONDUCTIVITY, see CONDUCTIVITY.

THERMAL EFFICIENCY. The ratio arrived at by comparing the amount of heat supplied to a heat engine with the amount converted into mechanical energy. In the ideal engine all available heat would be turned into useful work, but the average engine falls far short of this ideal, great quantities of heat being lost by radiation and friction.

Thermal efficiency is usually expressed as a percentage of the total heat supplied, small steam engines reaching an efficiency of from 12 to 15 per cent, internal-combustion engines of from 24 to 30 per cent, and large steam power-plants of from 36 to 40 per cent. The greater thermal efficiency of small internal-combustion engines is due to the fact that heat is generated and applied direct to the working piston, whereas in the steam engine the heat is first supplied to the water in the boiler, with consequent boiler and furnace losses.

Large steam power-plants, however, gain in efficiency because the quanti-

ties of heat used are greater in proportion to the losses. Some loss seems inevitable, owing to the fact that the working parts of an engine must be kept down to a reasonable working temperature, and heat is therefore lost in quantity by radiation.

THERMIONIC VALVE. An electronic device, more familiarly known as a radio valve, functioning by virtue of emission of electrons from a heated cathode. See RADIO VALVE.

THERMITE. A mixture of powdered aluminium and oxide of iron. If the mixture is ignited, great heat is evolved, the temperature rising to over 3500 deg. C. The chemical reaction is represented by the equation: $Fe_2O_3+2Al=Al_2O_3+2Fe$. Thermite is extensively used in welding tram lines and other castings.

THERMO-COUPLE. A junction between dissimilar materials that is able to exhibit thermo-electric effect.

THERMODYNAMICS. The study of the relations between heat energy and other forms of energy. There are three laws of thermodynamics. The First Law is that of the conservation of energy (q.v.), and states that a definite quantity of heat gives a definite amount of mechanical energy and a definite amount of mechancial energy yields a fixed quantity of heat.

The Second Law states that it is impossible, without some external agency, for heat to be transferred from one body to another body that is at a higher temperature. The Third Law states that the entropy (q.v.) of a body disappears at absolute zero. See JOULE'S EQUIVALENT.

THERMO-ELECTRIC EFFECT. The phenomenon which results in the production of an electromotive force when two thermo-couples connected in series are maintained at different temperatures. See THERMO-COUPLE.

THERMOPILE. A device for converting heat into electricity. It consists of a collection of pairs of thermo-couples, normally connected in series. See THERMO-COUPLE.

THERMOSTAT. An apparatus for maintaining temperature within close limits. It may consist of a bi-metal strip which opens and closes an electrical circuit controlling the supply of heat.

THITKA, see MAHOGANY.

THIXOTROPY. A quick-setting property possessed by certain gels, such as varnishes. The degree of setting cannot be measured owing to the induced flow resulting from mechanical agitation.

Thixotropic vehicles are in extensive commercial use for compounding quick-setting inks which aim at a rapid initial setting as a prevention of set-off. Actual drying then proceeds normally. Such inks appear of buttery consistency in bulk, but on shaking they flow readily and assume a "long" formation. Immediate setting takes place as the agitation ceases.

THORIUM (Th). Atomic no. 90; atomic wt. 232·12. A metallic element widely distributed in small quantities; the mineral monazite contains about 18 per cent of thorium. Thorium melts at about 1600 deg. C. It is tetravalent and radioactive, giving off an emanation or gas and β particles, so that it is gradually transformed into radium and finally into an isotope of lead. The best-known compound is thorium oxide (thoria), ThO_2.

THREE-ELECTRODE VALVE. A radio valve, also known as a triode, having three electrodes, viz. cathode, grid and anode. See RADIO VALVE.

THREE-PHASE FOUR-WIRE SYSTEM. A method of distributing electricity which employs four conductors, one of which is connected to the neutral point (q.v.), to afford a three-phase supply. See DISTRIBUTION and THREE-PHASE SYSTEM.

THREE-PHASE SYSTEM. A method of transmitting or distributing electricity, providing three interdependent voltages which are normally equal and spaced 120 deg. vectorially. See ALTERNATING CURRENT.

THREE-QUARTER FLOATING AXLE, see AXLE.

THREE-WIRE SYSTEM. A method of distributing D.C. electrical power, using two outer wires and a

neutral. The neutral is usually maintained at about earth potential. See BALANCER.

THROTTLE. A variable valve, generally of the butterfly type, placed in the induction pipe of an internal-combustion engine and connected by a suitable linkage mechanism to a lever convenient for hand or foot operation. The throttle varies the supply of air to the engine and hence the combustible mixture.

THRUST BEARING, see BEARING.

THRUST COEFFICIENT, see PROPELLER COEFFICIENTS.

THULIUM (Tm). Atomic no. 69; atomic wt. 169·4. One of the rare-earth metals, which has not been isolated. It is trivalent, but its compounds are unimportant.

THYRATRON. Also known as gas-filled relay or grid-controlled rectifier. A radio valve, generally a triode but sometimes of the screened-grid type, into which has been introduced a small quantity of inert gas such as argon. Current flows through the relay in the normal way by the passage of electrons from cathode to anode under the influence of a positive potential applied to the latter.

If, however, a sufficiently negative bias is applied to the grid before anode voltage is applied, the flow of anode current may be witheld. A subsequent increase of anode potential or reduction of negative grid bias to a critical value will allow anode current to pass again and the gas in the tube becomes ionized, exhibiting a characteristic glow.

Once ionization has occurred, the grid normally has no further control over the anode current, which can then be stopped only by breaking the circuit or reducing the anode voltage to an extremely low value for a sufficient time to allow the ions to disperse.

TIMBER. The trees providing timber for carpentry and joinery are called *exogens*, and are divided broadly into two classes: (1) hardwoods, from deciduous trees, and (2) softwoods, from coniferous trees. This classification does not denote the hardness of the wood, as the lightest and softest is a hardwood, but it distinguishes wood structure.

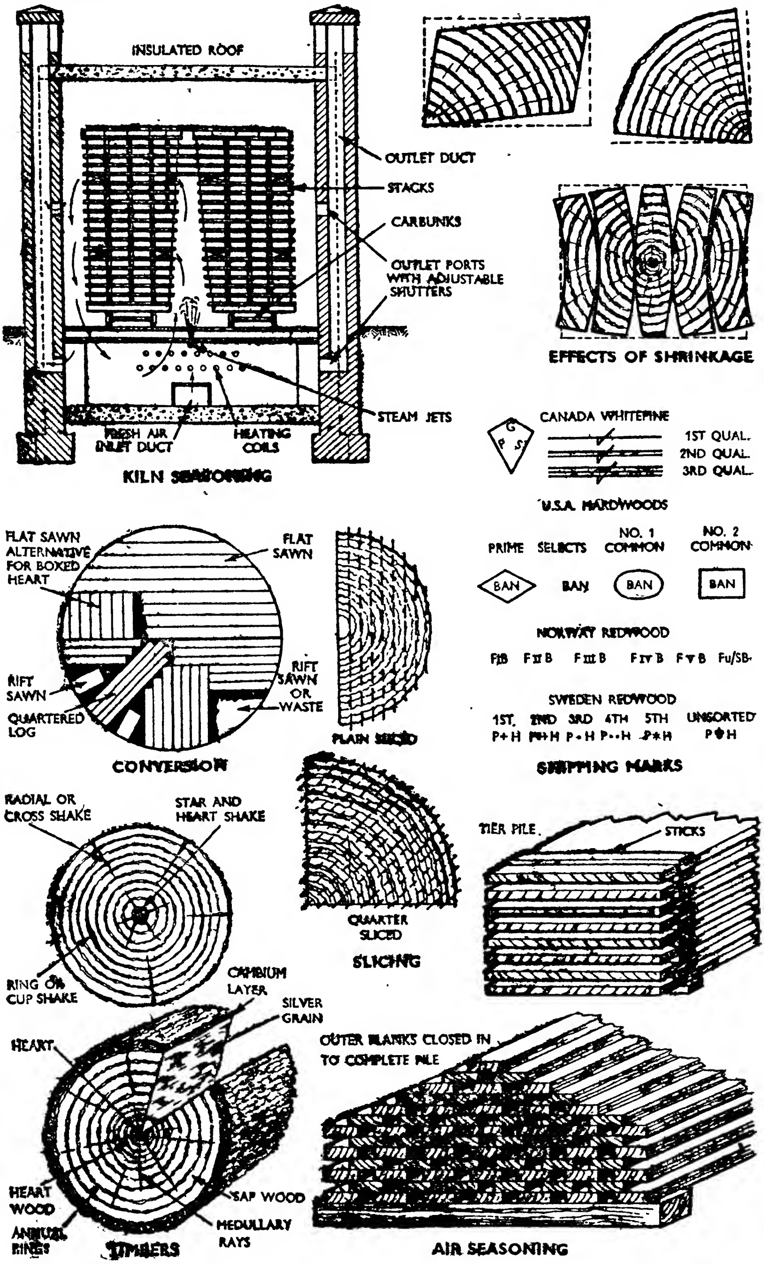
Softwoods are a lower form of plant life, and, generally, are softer and lighter than hardwoods. Softwoods are usually employed for constructional work and joinery, and include numerous genera and a large number of species. Hardwoods, of which there is a great variety, are mainly cabinet woods, and are seldom used in carpentry.

There is a great variety of woods available in Britain in normal times. Over 300 species are in common use, while more than 4000 woods have been introduced either for use or for scientific investigation.

Among the lesser-known hardwoods used in Britain are: ash, bagac, black bean, blackwood, camphor wood, cedars, chuglum, crabwood, ebony, eng, greenheart, gurjun, haldu, hickory, iroko, kokko, laurel, lunumidella, meranti, mora, myrtle, obeche, padouk, poplar, purpleheart, pyinkado, pyinma, rosewood, satinwood, serayah, silver greywood, thitka, toon, Rhodesian teak and mahogany, white bombway and white dhup.

CONVERSION OF TIMBER. Breaking down a log into practical lengths and sizes; the quality of timber depends to a large extent on the way this is done. If the cuts are tangential to the growth rings, it is called *flat* or *bastard* sawn, and produces *flat* or *slash* grain. This is the form of cut adopted for pitch pine, walnut etc., because the contrasting spring and summer wood produce bold, handsome grain. When the cuts radiate from the centre of the log it is called *rift* or *quarter* sawn, and produces *ribbon*, *edge*, *vertical*, or *straight* grain, and, in some timbers like oak, silver grain or ray figure. This is a more expensive method, and conversion is usually a compromise between the two methods. Shrinkage is much greater circumferentially than radially, hence rift-sawn wood is more stable and less liable to warp.

Other methods are employed for veneers, plywood etc. *Slicing*, which



Illustrated above are a number of details which have to be considered in the preparation and use of timber. The recognized shipping marks are also included.

is equivalent to taking a large, thick shaving off a flat surface, is adopted for figured woods. *Peeling*, or *rotary cutting*, is circumferential slicing of a revolving log. It produces unnatural grain, but is very economical; it is good for bird's-eye figure and other irregularities, and gives a bold handsome grain in Douglas fir etc., for plywood. *Boxing the heart* is a term used when a square piece is left at the centre of the log to include pith, heart shakes etc., and is usually applied to eucalyptus logs.

The converted wood is named according to the sizes of the pieces, as follows: *Balks*, squared logs of a size greater than 6 in. by 6 in.; *Deals*, European whitewood and redwood from 2 to 4 in. thick and from 9 to 11 in. wide, and U.S.A. softwoods from 2 to 5 in. thick and over 6 in. wide; *Boards*, softwoods under 2 in. thick and over 5 in. wide, and hardwood up to 1½ in. thick and of any width; *Planks*, softwoods over 2 in. by 10 in., and hardwoods over 1½ in. by 9 in; *Quarterings*, small square stuff from 3 in. by 3 in. (or sometimes 3 in. by 2 in.) to 4 in. by 4½ in.; *Battens*, softwoods from 2 to 4 in. thick and from 5 to 8 in. wide, or stuff of small section for special purposes, as tile battens, etc.; *Scantlings*, European softwoods over 2 in. thick, under 6 in. wide, and over 8 ft. long, and U.S.A. softwoods from 2 to 5 in. thick and less than 6 in. wide. Other terms used are flitch, die square, planking, planchettes, ends, thick stuff, masts, poles, casewood and pitwood.

Softwoods are sold by the *standard* (European), *board measure*, (American), *load*, *float* and *fathom*. The Petrograd standard of 165 cu. ft. is the most common. Manufactured goods, such as floor boards, are sold by the *square* of 100 sq. ft. Hardwoods are sold by board measure, or by cubic measure, and, in a few cases, by weight.

There are many softwoods in common use, including cedar (Western red), chil, cypress, numerous species of fir and spruce, hemlock, kauri pine, larch, Douglas fir, matai, podo, rimu, sequoia, tamarack and yellowwood.

Defects. The chief defects in wood are shakes, knots, wane, worm-holes, resin pockets, gum veins, bark pockets, burrs, callus, cross grain, upsets and wandering heart. Most defects decrease the strength of the wood, but in some cases, such as burr, they increase the decorative value.

Shakes. A cleavage in the annual rings.

Knots. A section through a branch embedded in the trunk of a tree.

Wane. A corner of the wood missing as a result of too economical conversion.

Resin pockets and gum veins. Excessive local accumulation of resin or gum.

Bark pockets. Bark embedded in the tree, due to injury and covered by later growth.

Burrs. Excrescences of dense woody tissue due to injury of the growing tree.

Callus. Tissue formed over a wound in the growing tree.

Cross grain. Applied to grain that does not run parallel to the faces of the converted wood.

Upset. A fracture across the grain.

Wandering heart. Due to a crooked stem in the early stages of the growth of the tree.

Diseases. Dote is the general term used in lumbering for localized incipient decay in wood, and includes doatiness, druxiness and foxiness. It is denoted by an unusual odour and discoloration.

All the various forms of decay are due to attack by fungi, which sometimes increases the decorative value of wood, but is usually destructive.

Dry rot is the worst enemy with which the user is concerned, and it requires drastic treatment. All infected wood must be burnt, and all surrounding materials specially treated with a strong preservative such as creosote, corrosive sublimate, or a proprietary preservative. The spores in the brickwork should be burnt with a blow-lamp. The cause of dry

rot is a damp, stagnant atmosphere, and this must be removed.

PRESERVATION. Many woods are naturally durable, but where decay may occur they should mostly be treated with a preservative. The most susceptible woods can be made durable by suitable treatment. Oils, chemical or mineral solutions are forced into the cells to increase the resistance to fungal or insect attack. The antiseptic should be permanent, easily applied, colourless, odourless and non-poisonous, and should have no bad effects on either wood or other materials in contact. Pressure impregnation is the most effective, but steeping or even surface application may be satisfactory with some preservatives.

There are many excellent proprietary preservatives, and advice from the manufacturers should be obtained.

SHIPPING MARKS (Timber) are private trade marks denoting the quality of the wood. They have no significance unless the firm concerned is known. The *seconds* of one firm may be as good as the *firsts* of another. There are numberless combinations of signs, letters and colours, and they may be branded, stamped, or painted on the timber. Four examples from different countries are given to show the variation.

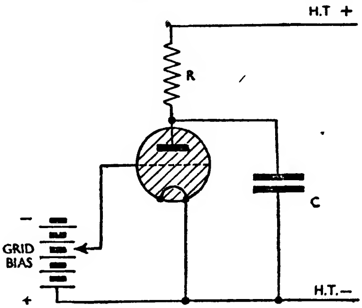
TIMBER CENTRES. Framed units used for the temporary support of arches during their construction. See TEMPORARY TIMBERING.

TIMBER CONNECTORS, see JOINTS.

TIME BASE. A term generally applied to a radio valve-oscillator circuit capable of producing a "saw-tooth" wave-form. Such an arrangement is used in cathode-ray oscillographs and television equipment. One of the simplest forms of time base incorporates a gas-filled triode or thyratron, and the circuit arrangement is shown in the accompanying diagram.

Its mode of operation is briefly as follows. The thyratron will not pass current until the anode potential reaches a critical value determined by the grid bias. On switching on, the voltage across C, which is also the anode voltage, rises as C becomes charged through R from the H.T. supply.

At a certain value, depending upon the degree of negative grid bias the thyratron conducts, C is rapidly



Simplified diagram which shows the basic circuit of a soft-valve, saw-tooth time base referred to in text.

discharged and the process then begins over again. The charging of the condenser C represents the relatively slow rise of voltage in the output wave-form and the sudden discharge corresponds to the rapid collapse or fly-back. Frequency of oscillation is determined primarily by the values of R and C, and amplitude by the value of grid bias.

An illustration of a typical saw-tooth wave-form appears under the heading CATHODE-RAY OSCILLOGRAPH.

TIME CONSTANT. A term applied to variations of such a nature that the rate of change at any time is proportional to the value of the quantity at that time.

Typical of such changes are the rise in temperature of an electrical machine, the growth of electric current in an inductive circuit, and the discharge of a condenser through a resistance. In the first two cases, the time constant is the time taken to reach 62·3 per cent of the final value.

In the second case it is given by $\frac{\text{Inductance (henries)}}{\text{Resistance (ohms)}}$, and in the third case by resistance (ohms) multiplied

by capacitance (farads). A growth curve for an inductive circuit is given under INDUCTANCE.

TIME SWITCH. An automatic switch designed to make or break an electrical circuit at a pre-set time or times.

TIMING GEAR (Auto. Engineering) This term applies to both the valve mechanism and the ignition system of an internal-combustion engine. The valves are timed to open and close at certain positions of the pistons in the cylinders, and this varies with different types and designs of engine. As a rough guide, the exhaust valve opens approximately 45 deg. before the piston arrives at the bottom of its stroke, or bottom dead-centre as it is termed, and closes at top dead-centre or just after. The inlet valve opens as the exhaust valve closes.

On many modern engines the exhaust valve closes after top dead-centre and the inlet valve opens before top dead-centre, so that both valves are open for a brief period at the same time. This arrangement is termed overlap.

Ignition Timing. The spark must occur within the combustion chamber of the cylinder when the piston is approximately on T.D.C. of compression stroke, with the ignition unit in a fully retarded position. In coil ignition systems the distributor is driven at half engine speed from the camshaft.

To time a distributor unit the drive is engaged when the contact-breaker points are just about to separate and the distributor arm is pointing in the direction of number 1 segment on the distributor cover.

The engine must be turned until number 1 piston is on top dead-centre of the compression-stroke. The same method is applied for magneto timing.

Valve Timing. The camshaft is driven, through a timing gear, at half crankshaft speed. This drive is carried out in one of two ways, either by a train of gear-wheels or by chain and sprockets, the latter system being more popular. Where chain drives are used, a tensioning device is necessary to take up slack developing from wear.

In order to time the valves of an engine the crankshaft is first turned to the position required and, with the intermediate gearing disconnected or the chain removed, the camshaft is set to the correct position in relation to the pistons. When the two settings coincide the drive is connected by meshing the gears or by fitting the chain, as the case may be. Timing should be carried out to the specifications of the manufacturer.

TIN (Sn). Atomic no. 50; atomic wt. 118·7. Ordinary tin is a white crystalline metal with a density of 7·3. It is harder than lead, but is easily rolled into sheet or foil. At 200 deg. C. it becomes brittle, and can be powdered. Below 19 deg. C. it gradually becomes a grey powder; m.p. 232 deg. C.; b.p. about 2270 deg. C.

The principal ore is the oxide, cassiterite, SnO_2, from which the metal is obtained by reduction by coal in a furnace. Tin is a mixture of ten isotopes, of which the most abundant have masses of 120, 118 and 116. Tin is largely used in "tinning", and it forms part of many alloys, such as anti-friction metal, bronze, bell metal, gun-metal, pewter, solder and type-metal.

Tin is tetravalent, forming stannous oxide, SnO, and stannic oxide, SnO_2. A variety of stannic sulphide is yellow, and is called "mosaic gold". Stannous chloride, $SnCl_2$, is soluble in water and is used as a mordant; stannic chloride, $SnCl_4$, is a heavy fuming liquid, which is soluble in alcohol and benzene. It is also used as a mordant.

TINNING. A part of the soldering process whereby metal parts may be joined together. The term is also applied to the practice of inducing a small quantity of solder to form a coating over a copper soldering iron, without which reliable results are unlikely to be obtained.

In joining metal parts, it is often convenient, for machining purposes, to solder together a number of small components which are then machined

as one article and subsequently melted apart. Steel can be soldered to steel if both portions are adequately tinned. They should first be thoroughly cleaned; heat is then applied and a liberal amount of flux spread over the surfaces. The solder is then rubbed on to the steel surfaces; any excess is removed with clean cotton waste and a thin uniform coating of solder is left. The surfaces having been thus "tinned", a small quantity of flux is smeared over them; they are then gripped together while further heat is applied, and the surfaces will adhere through the medium of the solder.

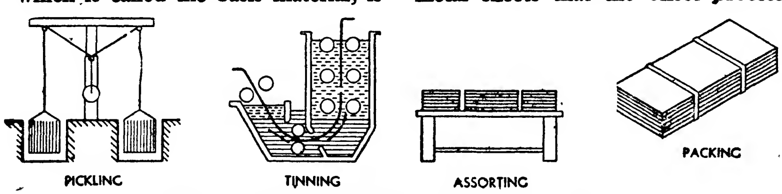
This process is sometimes called "sweating". When tinning a soldering iron, the end is cleaned by filing or grinding back for about ¾ in. Enough heat is then applied to the copper to cause the solder to melt; the solder is then pressed against the copper and will run over the surface to be tinned. It is a good plan to rub the copper with a piece of sal-ammoniac before the solder is applied. See SOLDERING.

TINPLATE. A mild-steel sheet coated with pure tin. The steel sheet, which is called the basis material, is usually low-carbon unalloyed mild-steel. It is coated either by the hot-dipping process (hot-dipped tinplate) or, more recently, by electro-deposition (electro-tinplate).

The main use of tinplate is for the manufacture of containers such as cans and boxes, and closures such as crown corks and screwcaps. For these purposes the thickness of steel is about 0.01 in., and the thickness of tin coating on each face of the steel is about 0·00009 in. For other purposes, however, tinplate may be made from much thicker steel (20 gauge or thicker), with tin coatings up to 0·001 in. thickness on each face.

The production of the steel base for tinplate may be in either of two ways: hot-pack rolling or rolling by the continuous process (see CONTINUOUS ROLLING). In the hot pack process (the older of the two) various rolling schedules may be used, a standard one being as follows. From either single bars or pairs, a pack is rolled out, doubled to form four sheets and re-doubled to form eight sheets. The packs are re-heated at each intermediate stage and, after the final rolling, are sheared along all four sides and opened.

Final assessment of the tinplate is made by assorters, who classify the material according to defects which have occurred during rolling and processing. See COKES (TINPLATE), and TERNE PLATE.



FOUR STAGES IN PRODUCTION OF TINPLATE

This series of illustrations shows, in diagram form, pickling and three of the subsequent operations in the manufacture of tinplate, in their correct sequence.

TIN PRINTING. For practical purposes, this is exclusively a lithographic offset process. Indeed, it was for the purpose of printing on metal sheets that the offset process was evolved, and it was used exclusively for this purpose for many years before being adopted for paper printing.

Any flexible sheet of even substance can be printed by this method, and the quality of decoration ranges according to need, from the simple polish tin or utility box to the exquisitely decorated casket. Printing is done in the flat sheet usually, but not essentially, on a single-colour machine, and due to the non-absorbent nature of

the metal, the inks are usually dried by stoving after each printing. Opaque backgrounds have to be printed or coated, but the natural metallic sheen can be used in conjunction with transparent inks to produce typical and exclusive effects. On the completion of printing operations, the sheet is varnished and this operation has either a preserving or a decorating effect, or both.

TIN-PRINTING INKS. These are similar to offset inks but must also be varnishable and withstand stoving temperatures up to 160 deg. F. for several hours, or higher temperatures for a lesser time, e.g. 270 deg. F. for twenty-five minutes, without discoloration or cracking.

The dried film must also be flexible, in order to withstand the severe die-stamping strains to which the finished sheet is subjected. Much transparent ink is used for tin printing. See LITHOGRAPHIC OFFSET INKS.

TIP SPEED (Aero. Engineering), see PROPELLER.

TIRILL REGULATOR. An electrical voltage regulator which controls the voltage of a generator between close limits by altering the excitation. In one position of the contact the voltage is slightly low while in the other position it is slightly high, and the contact vibrates between the two positions.

A device of this nature is often fitted to cars.

TITANIUM (Ti). Atomic no. 22; atomic wt. 47·9. A dark grey, crystalline metal of the carbon group; density 4·5, m.p. 1800 deg. C. It is stable in air, but oxidizes on heating and is dissolved by most acids.

Titanium is very widely found in natural substances, especially in ilmenite, a ferrous titanate, $FeTiO_3$, and in rutile, TiO_2.

Titanium is divalent, trivalent and tetravalent, and forms the oxide, TiO_2, a carbide, TiC, a dichloride, $TiCl_2$, a trichloride, $TiCl_3$, and a tetrachloride, $TiCl_4$. An amorphous variety of the oxide TiO_2 is prepared from ilmenite, and is used very largely as a white pigment which has exceptional covering power and is very permanent.

Titanium carbide, TiC, is used as a deoxidizing agent in the production of some varieties of steel. Titanium forms an alloy with iron, ferro-titanium, also used in the manufacture of steel.

TITANIUM DIOXIDE. A metallic substance used in the printing and allied industries for many purposes, although its initial cost is higher than that of the materials which it supersedes. It is supplied in very finely powdered form, and its chief features are chemical inertness, purity of whiteness and great opacity. It is used as loading in paper making (q.v.) and also possesses the properties of a pigment.

Owing to its great opacity it can be used sparingly. Not only is this economical, but it reduces the loss of paper strength which is induced by heavy loading (q.v.). Its use greatly increases the opacity of thin papers, such as air mail and Bible or India papers. Its chemical inactivity is a very important factor in papers for lithographic printing, and its effects are in contrast to those of casein. It is used in white and coloured coatings for boards and paper, and improves printability.

As a printing ink it has a far greater opacity than other white pigments, and it will withstand high stoving temperatures without discoloration. These two factors make it particularly useful for tin-printing inks and coatings. Drying properties are poor, and working properties are not good. Best results are therefore obtained by combining titanium dioxide, for its opacity and whiteness, with other pigments, according to their properties and the particular results which are required; chemical inactivity permits unrestricted mixing with other inks and pigments.

The non-poisonous nature of titanium dioxide also makes it a useful base for printing inks used on food wrappers.

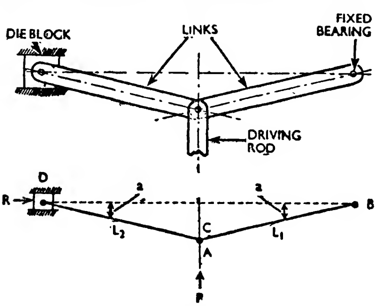
TITRATION. A method of finding out how much of a substance is

contained in a known volume of its solution. A small quantity of a liquid that is known to react with the solution is allowed to flow from a graduated glass tube with a tap at the bottom, and the operation is repeated until the reaction is complete. The amount of liquid required is a measure of the strength of the solution.

T.N.T., see BENZENE.

TOGGLE JOINT. A type of linkage used in various machines in which enormous pressure is required, e.g. stone crushers, drawing presses etc. The mechanical principle involved is shown diagrammatically in the illustration.

Two links L_1 and L_2 are hinged or pinned together at the centre C. The



In various machines, where very heavy pressure is required to be exerted at a given point, the toggle joint, illustrated above, is often employed.

other end of one link, say L_1, is anchored to a fixed bearing B, and the other end of link L_2 to a sliding die-block D. A driving rod A is also attached to the central joint C. It is through this rod that the force is applied, at right-angles to the line of action of the block D. A relatively large vertical movement of rod A causes only a comparatively small horizontal movement of block D, so that the force in A is vastly magnified at D. As the two links L_1 and L_2 come more and more nearly in line with one another, so the outward pressure on D rises steeply to its maximum.

Let R be the resistance to the die-block D, and P the force applied to rod A; let a be the angle between the centre lines of the links and the line joining the centres of B and D. Then $2\ R \sin a = P \cos a$. By substituting gradually diminishing values for a, the rapid increase in R, in relation to P, can be appreciated.

TOLERANCE. The amount of permissible deviation from a specified dimension in a machine part: the numerical difference between the largest and smallest permissible limits for any given dimension. Suppose, for instance, the maximum permissible length of a component is 4·500 in., and the minimum 4·495 in., then *on that particular length* the tolerance is 0·005 in.

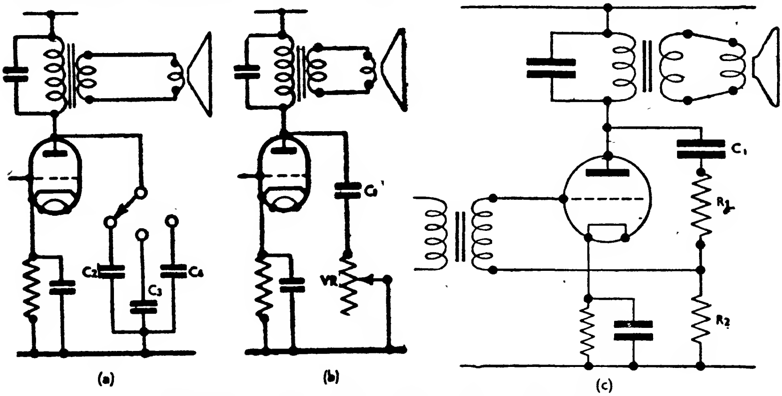
These tolerances are calculated by fixing the greatest and least clearances needed upon the various working surfaces. In fitter's work, tolerance is taken to mean this variation occurring in "identical" articles, in connexion with the various manufacturing operations and stages. Unilateral tolerance denotes deviation in *one* given direction only from a specified basic measurement, e.g. 2·500 + 0·003 (for a basic dimension of 2·500 inches). Similarly, 2·500 − 0·003 would denote a unilateral tolerance, but in the opposite direction. Bilateral tolerances show both upper and lower variations, e.g. $3{\cdot}35\ {}^{+\,0{\cdot}002.}_{-\,0{\cdot}003.}$

The methods of specifying tolerances vary greatly in different countries. To allow for temperature effects, a standard reference temperature is used, particularly for work on gauges. In Great Britain, this temperature is 68 deg. F.

TOLUENE, see BENZENE and COAL.

TONE CONTROL. A device for changing the frequency response of an audio amplifier, often incorporated in a radio receiver. It is used to compensate for acoustic characteristics, to reduce hiss or whistles and to give a pleasing effect to reproduction. In its simplest form, it usually consists of a method of reducing high (audio) frequency response.

In the illustrations overleaf one shows three condensers of different values C_2, C_3 and C_4, each of which can be connected at will, by-passing



DIFFERENT METHODS OF TONE CONTROL
In each case shown above, a certain amount of fixed control or compensation is provided by a condenser shunted across primary winding of output transformer.

the higher frequencies to any desired degree. The second shows another method; in this the tone-control effect is continuously variable between two limits and is determined by the setting of VR; C_1 is of fixed value. A somewhat more elaborate arrangement is in the third sketch; negative feed-back is employed here and a small proportion of the signal voltage at the anode is fed back to the grid circuit. A potential dividing network consisting of R_1 and R_2 (with a D.C. isolating condenser C_1) is placed in parallel with the valve and that fraction of the output voltage appearing across R_2 is introduced into the grid input circuit.

To avoid undue loss of output power, the combined value of R_1 and R_2 would be about ten times the normal load resistance represented by the output transformer. It is convenient to feed back about one-tenth of the output voltage; thus R_2 would be approximately one-ninth of the value of R_1.

The effect of this feed-back is to reduce gain, but this can be compensated for by providing greater input to the system. The reduction of harmonic content (distortion or over emphasis of the treble register) is reduced by about the same proportion as the gain, and a very considerable improvement in quality can be achieved. In superheterodyne radio receivers, tone control is often effected by employing variable band-width I.F. tuned circuits. Reduction of band-width will attenuate the remoter sidebands, with consequent reduction of output at the higher audio frequencies.

TONGUE AND GROOVE, see JOINTS.

TOON, see MAHOGANY.

TOOTH. The portion of the cylindrical surface of the rotor or stator of an electrical machine which lies between the slots. A diagram showing teeth is given under SLOT. One of the effects of slots and teeth is to produce variations in flux which give rise to a ripple in the e.m.f. wave. This is known as tooth ripple.

TOP COAT (Painting), see COVER COAT.

TORCH BRAZING, see BRAZING.

TORCHING. A process of plastering (q.v.) the underside of tiled roofs with lime mortar, so as to insulate the roof to keep out the wind and driving rain. Roofs are usually torched when tiles are hung on battens nailed direct to the roof rafters, but this is unnecessary if a roof is given adequate pitch and the tiles are arranged with an efficient lap. See PLASTERWORK.

TORQUE. The turning moment exerted by a rotating member. It is

measured in lb. ft. or lb. in. For example, if the cranking handle of a car is 9 in. in length and if an effort of 11 lb. is required to turn the crankshaft of the engine with the handle engaged, the applied turning effort, or torque, must be 99 lb. in. or $8\frac{1}{4}$ lb. ft.

TORQUE COEFFICIENT (Aero. Engineering), see PROPELLER CO-EFFICIENTS.

TORQUE MOTOR. A type of electric motor designed to operate against a torque (q.v.) such as might be produced by a spring. The motor does not rotate continuously.

TORQUE REACTION. When the propeller shaft of a vehicle applies a torque to the bevel pinion, which in turn transmits it to the road wheels, there is a tendency for the bevel pinion to roll round the bevel wheel and twist the axle round in the direction opposite to the rotation of the wheels. This is termed torque reaction, and it has be to counteracted on every such vehicle.

This is done in some cases by employing a torque stay, secured to the axle casing at the rear, and to a cross member at the front. The leverage of this stay overcomes the tendency of the axle to twist. Another method is to encase the propeller shaft in a torque tube, fixed to the axle casing and terminating at its front end in a ball. This ball fits within a cup on the rear end of the gearbox in which, though firmly held, it is free to move in response to the movement between the axle and the frame.

Still another means of overcoming torque reaction is by the springs, which are bolted rigidly to the axle casing, and secured at the front end to brackets on the frame by a spring-pin on which they pivot.

TOUGHNESS (Metallurgy). A term used to denote a state between softness and brittleness. Frequently associated with a metal's reaction to the notched-bar test. See NOTCHED-BAR TESTING.

TRACKING. An arrangement whereby the various tuned circuits in radio apparatus are made either to tune to the same frequency or to maintain a constant frequency difference at each setting of a main common control.

The term is used also in connexion with the tone arm in an acoustic or electric gramophone when it refers to the path followed by the needle from the outer edge to the conclusion of a record. Ideally, the path would be a straight line parallel to, and just ahead of, a radius drawn from the centre of the turntable to the point of needle contact at the outer groove, the lateral movement of the needle itself following this line. A sound-box or pick-up complying with this ideal, accurately, or as nearly so as possible, is said to track.

TRACK ROD, see AXLE.

TRACTOR (Aero. Engineering), see PROPELLER.

TRAMMEL (Carpentry), see COMPASSES.

TRANSFER GOLD LEAF (Painting), see GILDING.

TRANSFORMER (Elec. Engineering). Electrical transformers consist of two or more coils with which there is

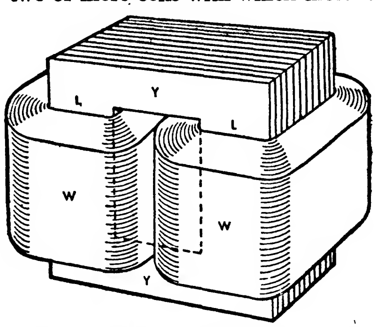


Fig 1. Diagram shows how the windings encircle the core of a transformer.

linked a common magnetic flux. The construction of a simple core-type transformer is shown in Fig. 1. The windings (W) might be primary and secondary (see PRIMARY WINDING and SECONDARY WINDING), but there would probably be half of each winding on each limb or core (L).

To ensure that as much of the flux as possible is common to both

windings, and to reduce the magnetizing force required, the two windings are built around a common iron core consisting of the cores (L) and the yokes (Y) to complete the magnetic circuit.

In practice, the coils are usually circular and the core is stepped, in order to get more iron into a circle of a given size. Moreover, the primary and secondary windings are well insulated from each other and from the core in such a way as to leave passages between them. One, or both, windings are frequently divided into packets between which there are spaces.

A three-phase core-type transformer is built in the same way, but it has three limbs instead of two.

An alternative construction is the shell-type. For a single-phase model the iron core has three limbs, the two outer ones being half as large as the central one, because they carry half the flux apiece. The windings surround the central limb and fill the two windows.

For efficient operation, a transformer must be cooled to get rid of the heat produced by the iron and copper losses. This may be achieved by natural or forced-air cooling, or, as is more usual, the transformer is immersed in oil contained in a tank. Circulation of the oil as a result of convection currents carries the heat to the walls of the tank, whence it is passed to the outside air. As a rule, the area of the tank is insufficient for this purpose, and it becomes necessary to provide additional area in the form of cooling tubes which give the transformer its characteristic external appearance.

Other methods of cooling involve the provision of coils of pipe carrying water, or the provision of separate oil coolers, rather like hot-water radiators. The latter may be cooled naturally or by blast. There is a standard code to describe the method of cooling. Thus, "Type ON" denotes an oil-immersed naturally-cooled transformer.

Oil loses its insulating properties when water gets into it, so it is advantageous to reduce the surface of oil in contact with the air. One way of doing this is to fit a conservator (q.v.). This and other fittings are illustrated in Fig. 2.

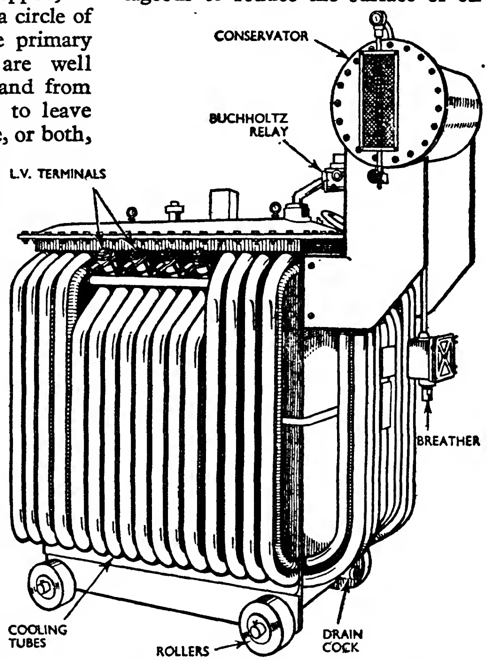


Fig 2. External appearance of 500kVA three-phase, oil-cooled Brush transformer for outdoor use. The tank alone is about 5 or 6 feet high.

When the temperature of the oil changes it expands and contracts so that air is driven out and drawn in, and to dry the air as it enters, a breather is fitted. This device consists of a vessel containing calcium chloride or silica gel. The latter has the advantage that it changes colour as it is used up, so that it gives a reliable indication when renewal is required.

Turning now to the behaviour of the transformer, it appears that

certain basic relations are common to all types. For practical purposes, it may be taken that the voltages of the windings are proportional to the numbers of turns, but in designing a transformer a small allowance must be made for internal voltage-drops. Except at light loads, the ampere-turns on the primary and secondary sides are equal, so that the currents are inversely proportional to the numbers of turns. Consequently the current is reduced if the voltage is increased and vice versa.

For lagging and unity power-factor loads the voltage falls slightly as the load is increased, but this change may be compensated by the use of tap-changing gear (see TAP-CHANGER).

A variation of the normal double-wound transformer is, the auto-transformer. In this machine there is but one winding, if it is single phase. Assuming that a step-up is required, the whole of the winding is connected across the secondary terminals but only a portion of it is connected to the primary terminals. The number of turns to be tapped is found by the rule already given. A disadvantage of the auto-transformer is that the primary and secondary sides are electrically connected. It is therefore not possible to use it as an isolating device, such as is required for low-voltage safety lighting.

For testing purposes it is sometimes necessary to provide a voltage for which no suitable transformer is available. The result may often be achieved by using two transformers with their primaries in parallel and their secondaries in series. The overall secondary voltage is either the sum or the difference of the individual secondary voltages, according to the way in which the connexions are arranged. Another possibility is to connect a single transformer as an auto-transformer. In this way it is possible to obtain the primary voltage plus or minus the secondary voltage (see BOOSTER).

For parallel connexions on both sides it is essential that the voltage ratios are the same and that the connexions are made the right way round.

In the three-phase case there is the additional complication that the phase-sequence must be the same for both, and that the internal connexions must be such that both have the same phase shift.

Instrument transformers, though they are apt to differ materially in appearance, do not differ in principle from a power transformer. It is easy to see that a voltage transformer (q.v.) behaves in much the same way as described above, but some difficulty is often found in understanding the operation of a current transformer.

The essential point to be realised is that whereas voltage transformers are supplied with a fixed voltage and draw such current as they need, the current transformer is series-connected and its primary current is decided by the rest of the circuit and not by the transformer. Consequently the voltage across its primary varies with, and adjusts itself to, the circuit and load conditions.

One other point worth mentioning is that a current transformer should not be left with its secondary winding disconnected. The secondary may be short-circuited and this should be done when the primary is carrying current and there is no other circuit on the secondary side.

TRANSFORMER (Radio). In radio work, transformers are classified according to the functions they perform. Thus, a mains transformer, (also known as a power transformer) provides the A.C. power supply to various parts of the main circuit.

Audio-frequency transformers almost invariably have laminated-iron cores and serve either to match one circuit to another or to isolate them where differences of D.C. potential exist. A radio-frequency transformer may have an air or dust-iron core, and its primary or secondary winding, or both, may be tuned according to requirements.

Other radio-frequency transformers, not of the conventional "wound" type, make use of the properties of

resonant transmission lines and are used for impedance-matching purposes.

TRANSIENT. An effect which persists for only a short period as the result of a sudden change in an electric current, voltage or sound; in particular, the conditions which obtain when an electric circuit has just been opened or closed.

TRANSMISSION (Auto. Engineering). The transmission of a mechanically propelled vehicle includes all the mechanism required to transmit the turning effort from the engine to the road wheels. The engine, clutch and gearbox are usually in one unit and are held more or less rigidly in the frame, whereas the rear axle, being connected to the chassis by the springs, is constantly varying its position in relation to the rest of the vehicle.

The transmission between the gearbox and the back axle must allow for this relative movement, and it is done by employing universal joints at suitable points on the driving shaft, or propeller shaft, as it is termed. Where the propeller shaft is of the open type and torque reaction (q.v.) is taken by the springs a universal joint (q.v.) is required at both ends of the shaft.

The front universal also incorporates a sliding joint to allow for the varying distance between front universal and rear axle as the latter moves up and down vertically. When the propeller shaft is enclosed it is necessary to employ a universal joint only within the ball joint at the gearbox end. In this case the rear axle moves in an arc and the distance between ball joint and rear axle is maintained constant.

TRANSMISSION (Elec. Engineering). One of the main advantages of electrical power is that it can be transmitted with small losses over great distances. Furthermore, it can be subdivided as much as necessary, so that it may be applied in large or small amounts according to need.

In order to achieve these results, it is important that the voltage at each stage in the process should be suitable. In general, long-distance transmission is most economical at high voltages, whereas low voltages are suitable for distribution to consumers. The actual voltage of transmission is a matter of economics. For the distances normally encountered in this country, the "Grid" uses 132 kV., but higher voltages are in use in other countries.

Other things being equal, D.C. transmission is more efficient than A.C., but in spite of this, A.C. is used because of the ease and efficiency with which the voltage may be changed by means of transformers. Direct generation at transmission voltages is not yet possible, the highest voltage at present in use in this country being 33 kV.

The general scheme is thus to generate at 11kV. or 33kV., to step-up the voltage to 132kV., and to transmit at that voltage to the main consuming centres. The voltage may then be reduced to 33kV. to feed secondary transmission lines leading to secondary consuming points, where another reduction to 11kV. may take place.

Large individual consumers of power are often supplied at this voltage, while the smaller consumers are usually supplied at 400/230V. by means of a three-phase four-wire system (q.v.) provided by yet another transformation.

In Britain, the problem is not so much how to move large amounts of energy from a generating point to a consuming point, as to interconnect generating points, each having its own local load, in such a way that it is possible for any one station either to supply its surplus power to the others, or to receive power from them when there is a deficit. The resulting economies in capital cost and running expenses, particularly when generation is confined to a few large and efficient units, are sufficient to justify the cost of the interconnexion scheme.

The British Grid system is a scheme such as this. Large cities and other suitable places have their generating stations, while the smaller

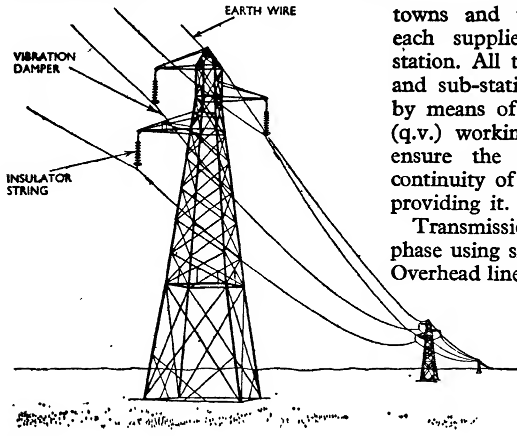
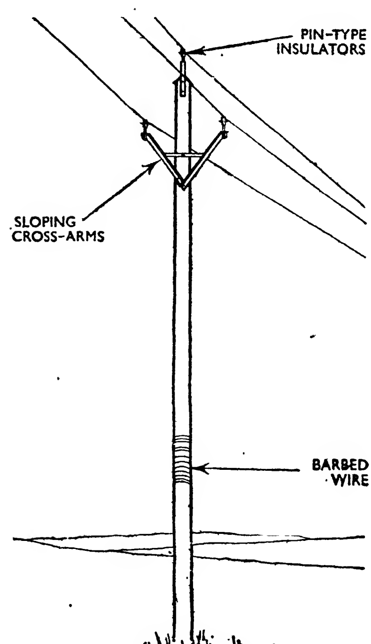


Fig. 1, above, shows a single-circuit tower as used for the 132 kV. sections of the British grid. Note grading rings on insulators and vibration dampers on lines. Height of towers is about 60 ft.; they are 900 ft. apart. **Fig. 2**, below, illustrates the normal wood pole for a medium-voltage transmission line, employing angle-iron cross-arms and pin-type insulators.



towns and the country areas are each supplied from a Grid sub-station. All these generating stations and sub-stations are linked together by means of a series of ring mains (q.v.) working at 132kV., so as to ensure the best balance between continuity of supply and the cost of providing it.

Transmission is normally three-phase using single or double circuits. Overhead lines are used in preference to underground cables because it is cheaper to do so. It is only in densely populated areas and places of special beauty that underground cables are used for transmission.

A single-circuit 132kV. tower is illustrated in Fig. 1. The system used is three-phase three-wire, the extra conductor being an earth wire linking the towers. The conductors are usually steel-cored aluminium. There is an inner core of stranded steel-wire, to provide the necessary strength, surrounded by a number of aluminium wires to carry the current.

For other transmission lines hard-drawn copper wire is widely used, especially at the lower voltages. Other materials available are cadmium copper, steel-cored copper, phosphor bronze-covered copper and sometimes galvanized iron.

The live conductors must be carried on insulating supports (see INSULATION), which are either pin or suspension units. The former types are similar to those used on telegraph poles, but larger, and suitable for using at voltages up to about 40kV. The suspension type is illustrated in Fig. 1 and consists of a chain of units, the number depending on the voltage.

Broadly speaking, this type is used for 33kV. upwards. One of the advantages of the suspension type is that if a single unit in the chain is damaged, it can be replaced, whereas if a pin-type insulator is damaged the whole unit must be scrapped. On the other hand, the pin system permits the use of lower towers to obtain the same

clearance between the live conductor and the ground.

A typical construction for a lower-voltage transmission line is depicted in Fig. 2 on the previous page.

The arrangement shown might be used for 11 kV. working. The sloping cross-arms are designed to reduce the number of short-circuits caused by birds, which are apt to perch on any horizontal bar. Sometimes, split-fibre tubes are slipped over the cross-arms to insulate the bird, and, on occasion, special insulated perches are provided in such positions that they will be used in preference to the cross-arms.

For overhead distribution, a common arrangement is to have four wires in a vertical plane, carried on reel-type insulators secured directly to the sides of the pole by D-shaped fixtures.

The somewhat cobweb-like appearance of this system is amply offset by its cheapness as compared with underground cables, and it is often used in rural districts.

It is sometimes thought that a cheap supply of electricity can be provided in any district through which a transmission line passes. That this is not so may be seen by considering the amount of equipment which is needed to provide such a supply.

The first requirement is a sub-station containing a transformer to reduce the voltage to 400/230V. The transformer itself is expensive, because, however small its output, it must be insulated to withstand the transmission-line voltage. Then there is switchgear on both the high-tension and low-tension sides. This, again, is costly, partly because it has to be insulated for the high voltages, but more especially because it has to be capable of breaking heavy currents.

However small the normal current may be, the current which will occur in the event of a short-circuit in the sub-station is limited only by the impedance of the circuits feeding it, and it is easy to see that with a high voltage, very large currents may flow under fault conditions. The circuit-breakers must be large enough to break these currents without being themselves wrecked in the process.

In addition to the items already mentioned, there are current-transformers and other gear for control and measurement purposes, and for operating the protective gear (q.v.), an auxiliary supply to operate the circuit-breakers, and a variety of other items, all of which help to make a sub-station such a costly construction that supply could not be afforded in this way to a single village, except at an exorbitant price.

TRANSMISSION LINE. In radio work generally, a pair of wires, sometimes also known as a feeder, used to transfer power, with a minimum of loss, from a transmitter to an aerial from which the power is to be radiated.

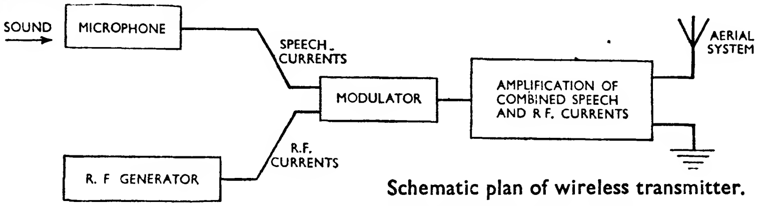
A common form of transmission line consists of two parallel conductors, kept a fixed distance apart by means of insulating spreaders or spacers placed at suitable intervals; it is known as an *open-wire* line. Two insulated wires twisted together without spacers to form a flexible line are called a *twisted-pair* line. A third type consists of a wire inside, and coaxial with, an outer metal tube or braiding. The inner conductor is separated from the outer by rubber, by beads or by some other form of insulating material at regular intervals. It is known as a *coaxial* line or cable. Another type employs a single conductor only and is called a *single-wire* feeder.

Transmission lines are classified according to whether they are resonant or non-resonant. A resonant line behaves almost exactly like a physically "elongated" tuned circuit and its resonant frequency is determined primarily by its length. Standing waves of voltage and current are present. A non-resonant line is so designed and used that it accepts and transmits energy at exactly the same rate at which it receives it. In this case, the energy transfer will be accompanied by travelling waves only

and the length of line (except for losses) is unimportant.

Non-resonant twisted-pair or co-axial feeders are also much used to connect short-wave aerials of the dipole type to radio receivers.

TRANSMITTER. A term broadly covering all the apparatus (except, generally, the aerial) necessary for the radiation of radio signals. The fundamental requirements are: a source of constant-frequency R.F. oscillations which are subsequently amplified and passed through various stages to the output; and a method of "keying" the oscillations for telegraphy, or of modulating them for telephony purposes.



Schematic plan of wireless transmitter.

The diagram shows the schematic outline of a broadcast transmitter. The term is also sometimes applied to a microphone.

TRANSVERSE TEST. A test, used mainly for cast-iron, in which the test-piece is supported at each end and broken by applying a load at the centre. The test-pieces are usually cylindrical and not machined before testing.

Five different sizes are recommended by the British Standards Institute. The diameter selected should approximate to the ruling section of the casting. The distance between the supports used for the different size bars varies as is shown in the following table:

Diameter of Bar	Distance Between Supports
0·6 in.	12 in.
0·875 in.	12 in.
1·2 in.	18 in.
1·6 in.	18 in.
2·0 in.	18 in.

The load in pounds required to break the test-piece is recorded, and if required the deflection of the bar in the test may also be measured.

TRAP. A U-shaped tube fitted to sinks, water closets etc., for the purpose of trapping and holding a quantity of water so that foul air cannot pass back from the drain to the building. They are made in various shapes, those in common use being known by the letter of the alphabet they happen to represent, such as P, S, Q. The P and S types as fitted to sinks and wash basins are shown in Fig. 1.

The principle is always the same. Matter or waste descending from the

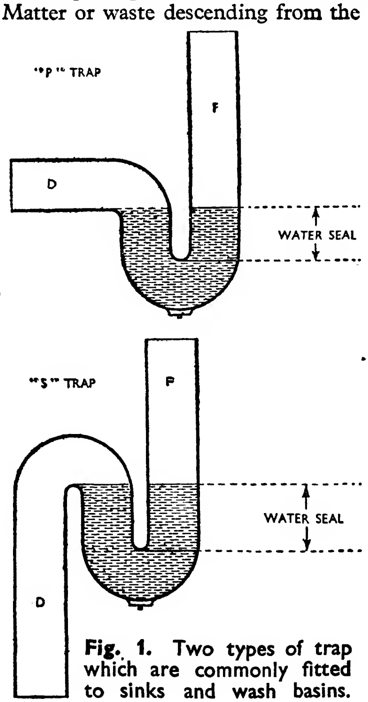
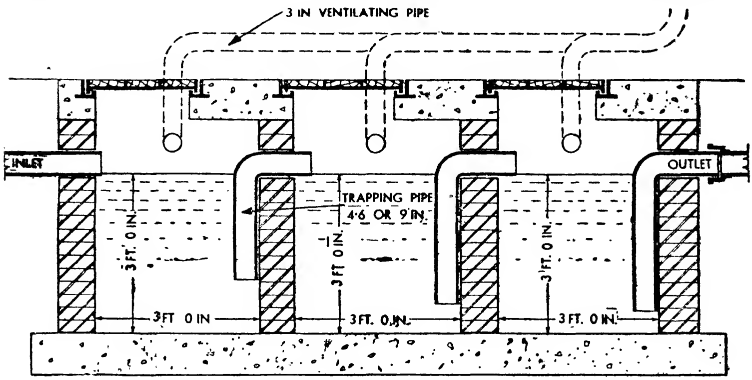


Fig. 1. Two types of trap which are commonly fitted to sinks and wash basins.



PLAN OF TRAP FOR INTERCEPTING PETROL

Fig. 2. It is an offence in law to discharge to a sewer water with inflammable liquid floating upon it. Above is shown the standard L.C.C. petrol interceptor.

fitment by the pipe F fills up the U part of the tube and the water level rises on both sides of the U until that on the discharge side flows down the pipe D; thus, some water always remains in the pipe to act as a water seal. Waste traps should be fitted with a draining plug at the base of the U for cleaning purposes.

Other traps are known as gulley traps (q.v.), grease traps and petrol interceptors. It is not permissible by law to discharge to the sewer water which may have quantities of inflammable oil or petrol floating on it, and the petrol interceptor (Fig. 2) is used, therefore, in such places as the washdown of a large garage. Grease

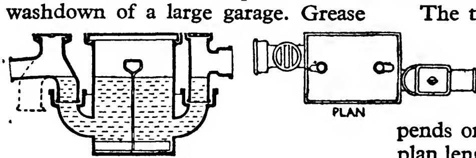


Fig. 3. Grease trap such as is fitted in kitchens of hotels and barracks.

traps (Fig. 3) are fitted to trap large quantities of grease and so prevent it congealing in and stopping drains.

T-REST. A form of tool-rest used mainly on the wood-workers' lathe. It takes the shape of the letter T, the upper horizontal bar being the portion on which the hand-tool is supported, while the vertical bar usually takes the form of a spigot which slides in a vertical socket.

The rest can thus be adjusted for height, and is locked in position by a set-screw. Double T-rests, with spigots and sockets each end, can also be obtained for hand-turning.

T.R.F. Tuned Radio Frequency.

TRIANGULATION. A term which may be applied to any system involving the use of triangles. In sheet-metal work, triangulation is one of the three methods employed in the drafting of patterns; it is based on the principle of dividing the surface of the object into triangles.

The true sizes of the triangles are found one by one and placed side by side in consecutive order to complete the full pattern. The method depends on the principle of placing the plan length of a line at right-angles to its vertical height, thus forming co-ordinates which give a diagonal equal to the true length of the line. In this way the three sides of the triangle which determine its true size are obtained.

Nearly all problems of pattern development may be solved by triangulation, although in some cases it is not so accurate as the methods of radial lines and parallel lines when these can be applied. Sometimes

development by triangulation may be effected without an actual plan view, but in every case where the true length cannot be obtained directly from the elevation, two distances at right-angles to each other may be used as co-ordinates to obtain the true length of a line which is to be used in the pattern.

TRICYCLE UNDERCARRIAGE (Aero. Engineering), see UNDERCARRIAGE.

TRIGGER CIRCUIT. A type of locking electronic switch. Such a circuit usually has two stable conditions: an applied pulse causes it to assume one state and another, usually different, pulse restores the circuit to its original condition.

TRIM. An aeroplane is said to be in trim about any of its three axes, when there is no resulting moment tending to rotate it about that axis.

The practical manifestation of trim is such that the aeroplane will fly in some desired manner (for example, in a glide for longitudinal trim, and straight and level for directional and lateral trim) without any force being applied to the controls in the pilot's cockpit, so long as nothing is done to disturb its state of equilibrium, such as changing the power output of the engine, lowering flaps etc. The necessary trimmed condition is obtained by adjusting the setting of the control surfaces, i.e. elevator, rudder and ailerons, by means of trimming tabs, spring bias etc. See SPRING BIAS and TAB.

TRIMMING CONDENSER. A small-capacitance variable radio condenser used in conjunction with ganging and generally associated with a main tuning control and used in this connexion for fine adjustments. The term is also applied to semi-variable pre-set condensers used for fixed-tuned circuits such as I.F. transformers.

TRIODE. A three-electrode radio valve comprising cathode, grid and anode. See RADIO VALVE.

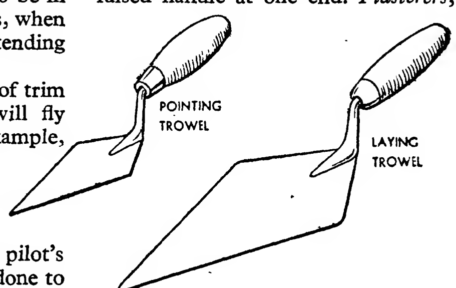
TRIP COIL. A coil through which the passage or failure of current initiates the operation of a circuit-breaker or similar device. See RELAY.

TRIVALENT, see VALENCY.

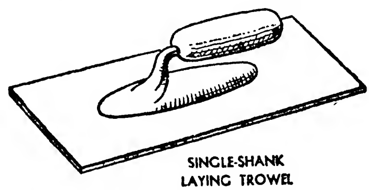
TROOSTITE. A decomposition product of austenite (q.v.), formed when the rate of cooling is somewhat slower than that required to produce martensite (q.v.). It is a very fine dispersion of iron-carbide in α iron. It is also produced by tempering martensite. Although scarcely resolvable under the microscope, it is easily recognised as a black etching-constituent, frequently outlining grains of martensite.

TROWEL. A tool for mixing and laying-on mortar, cement, plaster or other plastic material.

The *bricklayers'* trowel has a diamond-shaped blade of steel with a raised handle at one end. *Plasterers,*



Some common types of trowel. Above are shown two bricklayers' trowels; below, a plasterer's laying trowel.



laying trowels are rectangular in shape with a single or double-shanked handle attached to the centre of the top surface, as illustrated. These trowels get their special shape from the fact that they are used for smoothing large, flat surfaces, where any projection at either end would be an inconvenience. The *pointing* trowel has a blade about 5 in. long, and is used for placing mortar in the joints of brickwork for pointing (q.v.) or

finishing; laying trowels have a blade about 10 to 12 in. long and are used for spreading mortar.

TRUSSED ROOFS. When the distance between the walls is 20 ft. or more, without intermediate support, a trussed, or triangulated, frame is placed about every 10 to 12 ft. along the building. The frames carry horizontal members, ridge and purlin, running the length of the building. These members, with the wall plate, carry the common rafters, about 15 in. apart, which in turn carry the slates or tiles. see ROOF LIGHT.

BELFAST TRUSS. A special type used for large sheds, also called a *bowstring* truss. It is light in weight, intended only for felt or similar covering, but it may be up to 100 ft. in span. The lattices, about 3 in. × $\frac{7}{8}$ in., all radiate from a point about half the span down the wall. The method of building up these frames is to fix one string on the floor, with a camber of about $\frac{1}{2}$ in. to every 10 ft. of span. One of the bows is then bent to the required curvature by means of blocks fixed to the floor.

Filling pieces, $1\frac{1}{2}$ in. thick, are fixed at each end of the string, and the lattices are nailed to both string and bow, radiating in both directions. Short pieces of purlin are placed between the tops of the lattices to obtain the correct positions. The other string and bow are then nailed in position, and blocks nailed across the ends of the strings to prevent the bows from springing out of position.

KING-POST TRUSS. The most common type of truss for spans under 30 ft. There are several methods of fixing the king post and the foot of the principal rafter to the tie beam, one being shown under JOINTS. There is also considerable variation in the arrangement of the gutters, which may be eaves (q.v.) or parapet gutters.

A sketch is given under ROOF LIGHTS of a box gutter behind a parapet wall. The size of the members of the truss is governed by the loads on the roof, but the following method gives approximate sizes for an ordinary example: *Thickness of truss in inches = span in feet divided by five.* Therefore for 25 ft. span the thickness is 5 in. The struts and post are square. The depth of the tie beam is at least twice the thickness, and the section of the principal rafter in square inches equals the span in feet.

QUEEN-POST TRUSS. For spans between 30 ft. and 45 ft. it is usual to have a queen-post truss. The advantage of this roof is the space available in the rectangular part of the truss; but this is also a structural weakness, compensated in part by the heavy timbers and the metal straps, and by the introduction of a straining sill.

The details are similar to those in the king-post truss, except for the head of the queen post, shown on p. 486 by a separate detail. *Thickness of truss in inches = span in feet divided by* 7. For the other members proceed as for the king-post truss.

PRINCESS-POST TRUSS. A queen post truss with additional posts between the queen post and the wall, known as princess posts. With modifications, a princess-post truss can be used for spans up to 70 ft.

MANSARD TRUSS, also known as double-pitched roof and curb roof. In principle, this is a king-post truss supported by a queen-post truss. Like the latter, it provides space in the roof for a room, which is lighted by dormers in the steeper pitch, which should be about 70 deg. Above the curb, the pitch is about 30 deg.

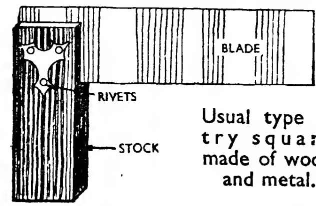
HAMMER-BEAM TRUSS. For open roofs to public buildings, where the timbers are on view, some variation of the truss is generally used. It may be designed for very large spans, or it may be a simple type (p. 486). The details and ornamentation depend upon the designer and the type of building. Thick walls are essential, unless piers or buttresses are provided, because of the thrust due to the omission of the tie beam.

Other types of roof and truss are usually composite or steel, and outside the scope of the carpenter.

TRY SQUARE. A tool for testing and marking-out a right-angle. The

usual sizes are 6 in. and 12 in., but 4 in. and 9 in. may be obtained. The illustration shows the usual type, consisting of a thin, steel blade riveted in an ebony stock faced with brass. Plates, usually brass, serve as washers for the rivets.

There are other types, such as all-metal and mitre squares, and the



Usual type of try square made of wood and metal.

edge of the blade is sometimes graduated in inches. Large wood squares, with a 2-ft. blade, are made by the joiner; and the carpenter uses a steel square which is graduated trigonometrically for obtaining bevel cuts in roofing etc.

TUCK POINTING (Building), see POINTING.

TUNED RADIO FREQUENCY. (T.R.F.) A term used to describe a radio receiver in which all the R.F. amplification is carried out at the frequency of the received signal, thereby distinguishing it from a superheterodyne receiver.

TUNG OIL. An oil, also known as Chinese Wood Oil, obtained from the nuts of a tree, formerly found only in China but now extensively cultivated in many parts of the world. This oil differs in behaviour from most others.

Unlike ordinary paint oil, tung oil when heated forms a jelly and eventually a solid which is difficult of solution.

Tung oil is dried mainly by polymerization, or alteration of its atomic structure, the transformation being unaffected by any moisture present in the atmosphere; it also resists the action of alkalis and alcohol.

The use of tung oil is confined by manufacturers to the production of varnishes, which resist the action of sea water and tropical heat, and bath enamels. Tung-oil varnishes, though expensive, provide the best possible finish for floors, counter tops and furniture; but they must be applied to the bare timber and any preparatory staining must be done in water without a glue fixative. Black japan and oil stains are unsuitable grounds for this type of varnish.

TUNGSTEN (W). Atomic no. 74; atomic wt. 184. A grey metal, density 19·1, m.p. about 3000 deg. C. or more; boils at a much higher temperature, perhaps above 6000 deg. C. It occurs in nature as wolframite, a tungstate of iron and manganese, and as scheelite, a tungstate of calcium.

The compact metal is obtained by compressing the powdered metal into bars and working these into rods and wire at a high temperature. It is largely used in the manufacture of filaments for electric lamps, for cutting tools, and as an alloy with steel and other metals for high-speed machine tools. It is divalent, pentavalent and hexavalent, forming carbides, W_3C, W_2C and WC, which are remarkably hard. W_2C and WC are used in the manufacture of cutting tools, sometimes alloyed with steel, nickel and cobalt.

Tungsten trioxide, WO_3, is soluble in alkali hydroxides, forming tungstates. Tungstate of soda, $5Na_2O.12WO_3.28H_2O$, has been used to impregnate fabrics so as to make them fireproof; another tungstate of soda has also been used as a mordant in dyeing.

TUNING. In radio and similar apparatus, the adjustment of a circuit containing inductance and capacitance so that it oscillates at the required frequency. The natural frequency of such a circuit depends upon the values of both its elements, and may be varied by adjusting either or both of them.

There are two methods of combining inductance and capacitance to set up a tuned circuit. First, the two elements may be in series, in which case the arrangement is said to be series-tuned and constitutes an *acceptor circuit*. Secondly, the inductance and capacitance may be in

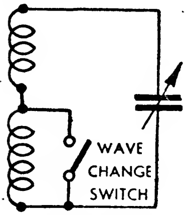


Fig. 1. Diagram shows how a tapped coil is used in conjunction with a variable condenser and a switch to cover two wavebands.

parallel, when they form a parallel-tuned or *rejector circuit*, being the type in most common use.

The extent to which a tuned circuit responds to frequencies just off resonance, in other words, the *selectivity* of the circuit or the sharpness of tuning, is determined by the circuit losses. As the losses increase, so the tuning becomes flatter. In radio applications it is generally desirable that circuits shall be fairly sharply tuned and thus it is important that the Q of the coil should be high.

Most modern radio receivers have a separate coil for each waveband, a common variable condenser usually being employed; older two-waveband receivers often made use of an inductance as shown in Fig. 1. For the longer waveband, the whole coil is in circuit but for the shorter band, part of it is cut out by means of a switch. Permeability tuning, i.e. varying the inductance of a coil by moving its dust-iron core, is sometimes used in radio receivers; the associated condenser has a fixed value. This method has the advantages of compactness and frequency stability and is relatively unaffected by mechanical vibration. It is, however, rather more expensive than the fixed coil-variable capacitance arrangement. For the resonant frequency of a tuned circuit, see OSCILLATION and RESONANCE.

Various methods of *automatic tuning* have been designed to save the radio listener the effort and time needed to rotate the tuning dial of a receiver to select the desired station. Among them is a telephone-like dial fixed to the tuning condenser. When a finger is inserted in a station name-hole and the dial rotated until it comes against a stop, the condenser is automatically rotated to the right position to tune in the station. This is accomplished by having behind each name-hole a stud which clicks into a spring-stop on a back plate.

Slightly more complicated mechanical methods of rotating the condenser to predetermined positions use a separate pushrod for each station. One of these arrangements, also known as push-button tuning, is shown in Fig. 2.

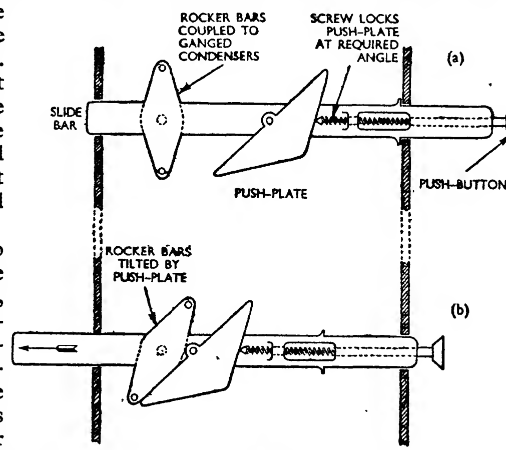


Fig. 2. General principles of a simple mechanical push-button tuning system.

It will be seen that, by locking the push-plate in any desired position, the rocker bars will be tilted when the button is pressed, turning the tuning condenser spindle as required.

The whole assembly shown will, of course, have to be repeated for each station which it is desired shall be automatically tuned. As expense and space prohibit the provision of more than eight or a dozen push-buttons, a normal manually tuned dial is still retained.

Even the best mechanical devices eventually become worn, and the

slightest slackness means unsatisfactory tuning. Most designers, therefore, have favoured electrical systems. In these, the push-buttons operate switches which introduce either condensers or coils pre-set for the reception of a particular station. For example, in the simplest arrangement, operation of a button switches out

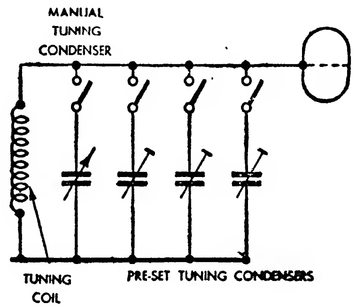


Fig. 3. System of push-button tuning in which pre-set condensers are switched across tuning coil, with main manual tuning condenser shown disconnected.

the main variable tuning condenser and connects semi-variable trimmer-type condensers across the tuning coil (Fig. 3).

An arrangement which is naturally more stable employs a fixed condenser and a series of permeability-tuned coils switched in at will (Fig. 4).

In superheterodyne receivers, tuning drift is most harmful in the oscillator stage, since this determines whether or not the correct frequency will be applied to the I.F. amplifier. Usually, therefore, while a system,

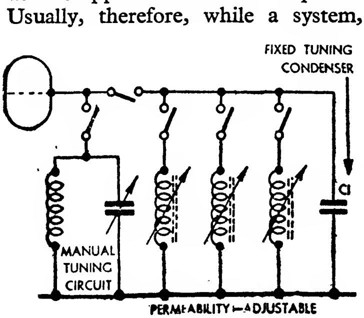


Fig. 4. Arrangement using a fixed condenser and permeability-tuned coils.

such as is shown in Fig. 3, can be left in the aerial circuit, more stable oscillator tuning is achieved by using a separate coil for each station. For push-button operation, the normal tuning coil and condenser are switched right out and a button brings into circuit, first, a very stable fixed tuning capacity (Cl, Fig. 4), and then a coil whose inductance can be accurately adjusted for frequency.

Even when all the coils and condensers in a tuned circuit are individually stable, frequency drift may be caused by variations in the valves and other parts owing to change in temperature as the receiver warms up. For this reason, oscillator stages often include a temperature-compensating condenser which changes its capacitance in a contrary sense to the changes occurring elsewhere.

The most elaborate system of automatic tuning is motor driven. In this arrangement, the gang condenser is rotated to the required position by a miniature reversible electric motor operated by current from a special winding on the mains transformer, various methods being used to stop the motor at as nearly as possible the correct moment. To correct inevitable errors in the stopping position an electrical method of automatic frequency-control (A.F.C.) is incorporated.

In superheterodyne sets, a slight error in the tuning of the aerial circuits is of relatively little importance, provided that the oscillator frequency is correct. The A.F.C. circuit is, therefore, designed to correct any divergence of oscillator frequency; for example, if when the motor stops, it leaves the oscillator running too slowly, the A.F.C. acts so as to raise its frequency electrically by the required amount.

A.F.C. is also incorporated in automatic tuning systems other than motor tuned, but its use is confined to superheterodyne receivers. An A.F.C. circuit consists of two main parts. The first contains a discriminator valve, which is a double diode connected to two specially tuned circuits

added to the last I.F. transformer. One diode or the other conducts according to whether the I.F. be too high or too low.

The diode output voltage is applied to the second section of the arrangement—a control valve connected in the tuning circuit of the frequency changer. Discrimination output alters the effective reactance of the control valve and so corrects the oscillator frequency.

TUNING INDICATOR. A device used in a radio receiver to show whether or not it is correctly tuned. There are various types of tuning indicator, the most popular incorporating a miniature cathode-ray tube. See CATHODE-RAY TUNING INDICATOR and "MAGIC EYE".

TURBINE. A power unit which works on the principle of the water wheel; i.e. a contrivance for converting the kinetic energy of a fluid or gas into rotary mechanical motion. Modern turbines can be driven by steam, water or gas.

The expansive (static) energy of steam is converted into moving (kinetic) energy by means of a nozzle, which directs the flow of steam on to a series of vanes set on the circumference of a drum. These vanes are set at an angle and, in this respect, the turbine takes more the form of a modern windmill. Turbines, however, can be of axial or radial flow, and of either the impulse or reaction type.

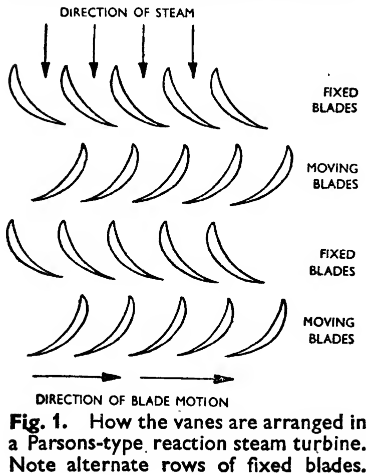


Fig. 1. How the vanes are arranged in a Parsons-type reaction steam turbine. Note alternate rows of fixed blades.

Fig. 1 shows the blade arrangement of a Parsons-type reaction turbine. Here there are alternate rows of fixed and moving blades, or vanes, the moving vanes being fixed to the rim of a drum or rotor, while the fixed blades are attached to the outer steam-tight casing, pointing inwards between the rows of moving vanes.

Steam enters the casing at the high-pressure end and is deflected by the first row of fixed blades so that it impinges upon the row of moving blades. From these it escapes in the reverse direction, is again reversed by the next row of fixed blades, and gives a further impulse to the second row of moving blades. This is known as axial flow because the flow of steam is parallel to the axis of the rotating drum.

Turbines have been designed which make use of the outwards, or radial, flow of steam from the centre of a drum, but axial flow is more common. In the pure impulse type of turbine, steam escaping from a jet gives motion to a rim of blades without any use being made of the back pressure or reaction; it is to make use of this back pressure that there are stationary blades between the moving blades in the reaction turbine.

The most important feature of all turbines is the shape of the blades and the angle that they present, for the speed may be greatly affected by an alteration in the shape of the blades or in the direction of flow of the incoming steam. The importance of the angle is illustrated by the fact that an ice-yacht sailing before the wind can never attain a speed greater than the speed of the wind that is pushing it. Theoretically, if there were no friction, its speed would be exactly the same as the wind-speed.

If the yacht be turned so that it sails at an angle across the wind, however, some pressure will always be exerted on the sails, no matter how fast the yacht travels.

The turbine is highly satisfactory for using steam down to the last

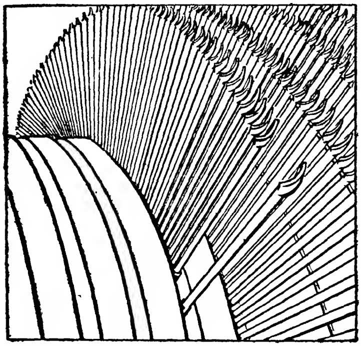


Fig. 2. Further details of arrangement and fixing of blades in a steam turbine of the Parsons axial-flow reaction type.

limit of expansion. At high pressures, however, the steam is not so fully utilized as in the reciprocating type of steam engine. For this reason low-pressure turbines are often combined with reciprocating engines to make use of the steam exhausted from the low-pressure cylinder. They are used for high-speed marine work, geared down to the speed of the propeller, for generating electricity and in various forms of power plant.

The turbine works best at high speeds, and is almost useless if the speed has to be kept low. For the purpose of expansion, stepped drums are used, the steam entering at the end with the smallest diameter and expanding towards the large diameter.

As regards construction, Fig. 2 gives some idea of the fitting of rotating vanes in a Parsons-type reaction turbine. The method of attaching the blades to the drum is important, for in turbines with a shaft revolution of only 750 per minute the blades attain a velocity of 1,378 feet per second and tremendous power is exerted by centrifugal force.

Assuming a single blade to weigh half an ounce, its fastening is subjected to a stress of 15 cwt. when the drum is running at its normal speed, and the mechanical tendency to break away from its mounting is tremendous. The blades vary in length from $1\frac{1}{16}$ in. to $10\frac{1}{2}$ in. in a $22\frac{1}{2}$ in. and 54 in. blade ring respectively, the shorter blades being used at the high pressure end. A turbine being non-reversible, separate units are used for forward and reverse speeds.

The Brush-Ljungstrom turbine is a modification of the reaction turbine and gives high efficiency with comparatively small dimensions. It works on the principle of double rotation and is of the radial flow type. The horizontal blades are mounted in rings carried by two parallel disks rotating in opposite directions. Steam is admitted to the centre of the innermost ring and flows radially outwards

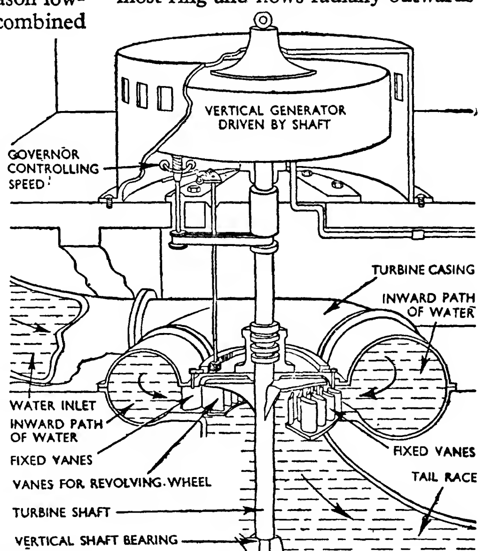


Fig. 3. Water turbine showing vertically mounted rotor shaft and generator.

through the remaining stages until it emerges into the casing, from which it passes to the condenser.

Leakage is minimized by the small diameter of the high-pressure rings. The rings on one disk are interleaved with those on the other, so that the

relative speed of adjacent rings is equal to twice the actual running speed. A 3000 r.p.m. turbine of this type is thus equivalent to a single rotation reaction turbine having the same number of stages at the same diameters but running at 6000 r.p.m.

For convenience and effectiveness the majority of water turbines are mounted vertically; that is to say, the rotor shaft is vertical and often directly coupled to generators also mounted on end. The one in Fig. 3 overleaf has both fixed and revolving vanes, with the water flowing radially inwards to the centre of the wheel, where it falls away into the outlet.

TURBO-GENERATOR. An electrical generator intended to be driven by a steam turbine. It is characterized by the relatively great length in comparison with diameter of the rotor. See ALTERNATOR.

TURKEY STONE, see OILSTONE.

TURN-AND-BANK INDICATOR. An instrument used in blind flying to indicate the rate at which the aeroplane is turning and whether the correct bank is being applied. The turn is recorded by a gyro unit, and is indicated in both direction and magnitude by a pointer, and the correctness of bank by either a pendulum actuating another pointer, or by a ball in a curved glass tube.

When the aeroplane is turning, horizontal forces due to the acceleration, as well as gravitational forces, act on the pendulum or ball. The correct bank, in relation to the turn being made, occurs when the resultant of these forces acts parallel to the normal axis of the aeroplane, so that the ball will then be in the zero position.

TURNOVER BOARD (Foundry Work). A wooden board on which the pattern is laid in order to ram the drag-half of the mould.

TURPENTINE. A hydrocarbon in the form of a clear, colourless liquid obtained by distillation from the resinous secretions of pine trees. It has a characteristic odour and is very combustible, burning with a smoky flame. It mixes well with alcohol, benzine and petroleum, and is a good solvent for oils, fats, waxes and the softer resins.

Exposed to the atmosphere, turpentine thickens by the absorption of oxygen; prolonged exposure causes it to become resinous, with considerable loss in bulk by volatilization. When extended as a thin film as in painting, the evaporation is accelerated and the oxidation, although less, is more complete, the residue being a hard resinous product and a valuable addition to the dry film.

Turpentine is used by painters mainly as a diluent for oil paint. In certain types of painting which have to dry with a dull finish, it may be the chief liquid used in combination with the pigments (q.v.). It is also used in the fabrication of varnishes and enamels, but should not be used by the painter as a diluent or thinner of those materials which are supplied ready for application.

TURRET PRESS. A device originally introduced to obviate frequent tool changes on small punch presses. The turret principle has now rapidly extended, and multiple-station presses up to 5000 tons are in production. In the small punch press approximately 12 separate tool stations may be provided, and all may have different-sized tools. The turret is rotatable and the required tool, or station, is plunger-selected in any order, at will.

In large machines, four or six die-stations may be used, the latter providing the same selectivity of die-slide as the former—any one die-slide being available for movement into the press, independent of its relation to the preceding slide. In the six-station design, all die-slides enter the press endways, provision being made for stock racks between the slides. It is possible to use rubber tools (q.v.) with this type of machine, as, since the slides all enter endways, they occupy different positions within the press bed; hence the rubber pad must be rotated accordingly.

This rotational movement is synchronized with the die-slide action

and control must be so arranged that as the die-slide enters the press, the rubber pad automatically and simultaneously rotates to the proper position. If the diametrically opposite slide enters the press after a given slide has been withdrawn, the rubber pad remains in its original position, since this suffices. In the latest designs, the press can exert different pressures on the various die-slides, each slide being provided with its own pressure adjustment, so that if a light pressure is desired on one pad and a heavy one on another, the desired strength is selected automatically.

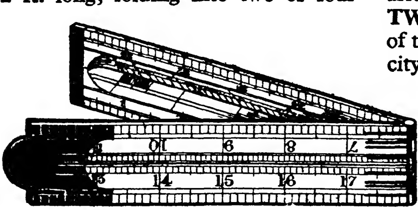
The advantages of this type of plant are: (*a*) multiple operations can be accomplished on one machine without changing tools; (*b*) idle time of the press for loading and unloading the dies is cut to a minimum, since these operations are accomplished independently while the station is out of use; and (*c*) economy in floor space.

TWEETER. A small loudspeaker specially designed to reproduce the upper musical register, the middle and lower notes being dealt with by a *woofer* (q.v.).

TWISTED-PAIR LINE, see TRANSMISSION LINE.

TWO-ELECTRODE VALVE. A radio valve, also known as diode, with two electrodes, that is to say, a cathode and an anode. See RADIO VALVE.

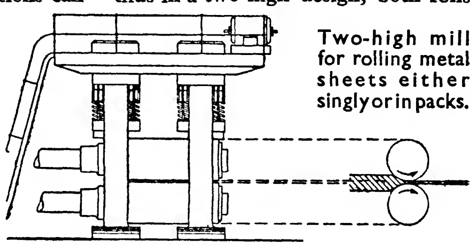
TWO-FOOT RULE. A measuring tool, as shown in the illustration, 2 ft. long, folding into two or four sections for convenience in carrying about. Many carpenters, however, prefer to use a four-fold 3 ft. rule, as it is more convenient for measuring openings etc.



Two-foot rule folding into four sections for convenience of carrying.

The inches are graduated, usually with two as the multiple, into halves, quarters, eighths etc., but twelfths and tenths are often included. On some rules the inner edges are bevelled and graduated in different scales.

TWO-HIGH MILL. All rolling mills for the production of sheet metal are classified according to the number of rolls per stand as being two-high, three-high or four-high. In each case there is a minimum of two work rolls; thus in a two-high design, both rolls must impose all reduction of thickness as well as maintaining the surface quality and gauge accuracy of the material.


Two-high mill for rolling metal sheets either singly or in packs.

TWO-HIGH MILL

Two-high mills are invariably used in the older-fashioned system of rolling, in which sheets are rolled singly or in packs (see BREAKING-DOWN; ROLL GRINDING). There are also modern designs of good mechanical efficiency for the production of non-ferrous sheets. The rolls are vertically disposed in the housings, the diagrammatic sketch showing the arrangement. See FOUR-HIGH MILL.

TWO-PHASE SYSTEM. A system of transmitting or distributing electricity wherein two interdependent voltages are provided. These are normally equal and their vectors are at right-engles.

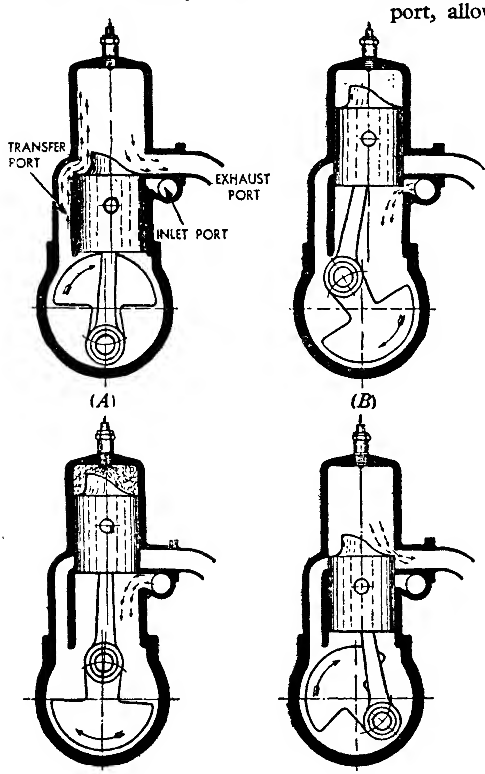
TWO-STROKE ENGINE. A two-stroke or two-cycle internal-combustion engine is one in which a power stroke takes place once in every complete revolution of the

crankshaft. A two-stroke engine, such as that shown in the accompanying illustration, is chiefly used as the power unit on light-weight motor cycles. Its great advantage lies in its simplicity of design and low production costs, owing to absence of valves and valve-gear mechanism.

Its other component parts are as in the four-stroke engine, but the flywheel is fitted externally. Ports in the cylinder and crankcase, to control the flow of mixture and burnt gases to and from the cylinder, take the place of valves. The carburettor is mounted on the side of the cylinder barrel and communicates with the interior of the engine through an inlet port in the cylinder wall. An exhaust port in the cylinder wall allows burnt gases to escape into the exhaust system and a third port, known as the transfer port, allows gases to pass from the crankcase to the cylinder.

A two-stroke engine operates as follows: on the upward stroke of the piston the volume of the space below the piston increases and creates a partial vacuum in the crankcase; as the piston rises further into the cylinder the inlet port is uncovered and the explosive mixture of air and petrol vapour is drawn into the crank chamber from the carburettor. As the piston descends it compresses the mixture until the transfer port is uncovered, allowing the mixture to pass to the upper part of the cylinder.

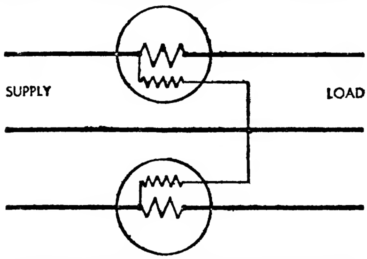
When next the piston ascends this charge is further compressed and simultaneously another charge enters the crankcase. At approximately T.D.C., the mixture is ignited and rapid expansion occurs, forcing the piston down the cylinder to produce the required power as well as compressing the new charge in the crank chamber. When the piston reaches a certain point in its downward travel the exhaust port is uncovered and the burnt gases flow out into the exhaust pipe and silencer. The transfer port is positioned slightly below the exhaust and, when this in turn is opened, the incoming charge assists in forcing the remainder of the expanded gases out; the cycle is then repeated. The



Two-stroke cycle in a Villiers engine. *A* shows induction and exhaust stroke, with mixture passing from crankcase to cylinder and burnt gases escaping through exhaust port. In *B* partial vacuum in crankcase causes mixture to be drawn in from carburettor as piston nears top of stroke and compresses mixture in cylinder. *C* shows commencement and *D* finish of power stroke. Note three ports and how they are controlled by piston strokes.

top of the piston is provided with a baffle which deflects the incoming charge to the top of the cylinder. To maintain efficiency it is imperative that all joints be kept gas-tight.

TWO-WATTMETER METHOD. An electrical circuit whereby the total power in a three-phase three-wire system may be measured by means

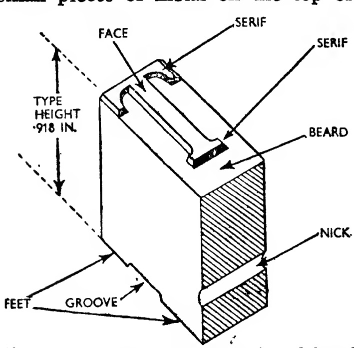


Connexions for power measurement by two-wattmeter method. Total power is sum of the readings. If one set of connexions has to be reversed to obtain a reading, that reading must be counted negative and subtracted.

of two wattmeters, or a single wattmeter having two movements. For a four-wire system three wattmeters are needed. The diagram shows the two-wattmeter circuit.

TYNDALL EFFECT, see COLLOIDS.

TYPE. Small blocks of metal upon which the letters of the alphabet are punched. There are hand types, as illustrated, and machine types (see TYPESETTING MACHINES). Monotype and hand types are similar, being small pieces of metal on the top of



Illustrated above is a sample of hand type, depicted in perspective to show type face and details of the mounting.

which is cast the letter or character. Linotype and Intertype machines cast a whole line of type in one piece, and this is called a slug.

Formerly, type sizes and forms were known by names, but in recent years a point system of measurement has become the general standard. The "point" equals roughly one-seventy-second part of an inch, and all modern types are multiples of this unit. Following is a table showing the modern point system as applied to the old names:

Excelsior	3	points.
Brilliant	4	„
Diamond	4½	„
Pearl	5	„
Ruby	5½	„
Nonpareil	6	„
Emerald	6½	„
Minion	7	„
Brevier	8	„
Bourgeois	9	„
Long Primer	10	„
Small Pica	11	„
Pica	12	„
English	14	„
Great Primer	18	„
Two-line Pica	24	„
Five-line Nonpareil	30	„
Three-line Pica	36	„
Seven-line Nonpareil	42	„
Four-line Pica	48	„
Five-line Pica	60	„
Six-line Pica	72	„

Type styles are many and varied, but all may be divided, very broadly, into three main types: Bold Face, Roman and Italic.

Bold Face is a black letter with or without trimmings, or serifs, and is used to call attention to some heading or paragraph; Roman, which is the most popular for all literary and journalistic work, consists of thick and thin lines, with serifs (feet or heads); and Italic is a semi-cursive style used again to call attention to some particular word or heading.

TYPE METAL. Alloys are used, on account of their low melting-point, in casting type for printing. They consist mainly of about 80 per cent lead, with the remainder made up of antimony and tin in varying pro-

portions. The result is an alloy which melts easily and rapidly in the Linotype or similar machine and yet gives a type face hard enough either for printing direct, as on the flat-bed machine, or for forming a papier mâché mould known as a flong (q.v.), from which can be cast a flat or semi-cylindrical stereo. See TYPESETTING and TYPESETTING MACHINES.

TYPESETTING. The process of arranging separate letters of type in words and sentences for printing purposes, done today very largely by machinery (see TYPESETTING MACHINES). Hand-setting is practised chiefly in large type for head-lines or displayed matter for handbills, posters etc.

The type is arranged in cases, an "upper case" for capitals, and a "lower case" for small letters. These cases are simply trays divided into sections by partitions, each box, or partitioned section, containing a number of the same characters. The partitions are not equal in the lower case, however, those letters in the English language most frequently used having a much larger box than the others.

Composing is done on a "stick"—a narrow metal tray so arranged that it has a sliding flange which can be set to the "measure" or width of the line required. The pieces of type are slid into this stick with spaces between the words, and when the line is completed it is made to fit the measure exactly by the insertion of extra spaces of different widths, so that each line becomes tight and ends evenly. This is known as justification. When the stick is full, the compositor slides the type on to a "galley"—a metal tray—and from this galley, when full of type, is taken the "pull", or proof, to be sent to the printer's reader.

The corrected proof is returned, the necessary alterations made, and the galley of type is then ready to be slid into the "chase" (q.v.), or forme. This is made of metal, and is placed on a flat-topped, smooth metal table, sometimes on wheels, known as a "stone" because originally such tables had smooth stone surfaces. The various pieces of type, all of uniform depth—type height is 0·918 in.—must have a smooth surface on which to rest, or the type surface would not be in the same plane.

All the printing surfaces must be exactly 0·918 in. high, and the wood or metal units used to fill-in the blank spaces are of lesser height to avoid inking.

When the chase has been properly made tight with spaces, rules and quads—rules below type height which thus leave a "white" on the printed paper—the chase is locked up and is the forme from which either the printing is done direct, or from which a papier mâché mould, or flong, is made for the casting of a stereo. See FLONG, TYPE METAL and TYPE.

The unit of measurement for surface space is the "em", a square roughly the size of the character "m" in the particular type used; the measure is thus spoken of as being so many "ems".

The setting and justifying of lines may be done (1) by hand from movable types; (2) semi-automatically, as in the Ludlow system, by hand setting and justifying matrices and casting by machine; (3) by mechanical means in the form of lines of type or slugs as in Linotype, Intertype and Typograph, or in the form of separate type characters as on the Monotype machines.

In addition to type, ornaments and rules of various thicknesses, the forme may contain illustrations such as linocuts, woodcuts, wood-engravings, half-tones in copper, zinc, rubber or plastics, line blocks or zincos and stereotypes. Two or more of these may be used in a variety of combinations.

All the various units are assembled on a metal bench, placed within the steel chase and secured by means of quoins, which are either wedges of wood or expanding mechanical devices of various kinds.

A hand proof is taken, errors marked and corrections made, when

the forme is ready for the letterpress printing (q.v.) machine.

TYPESETTING MACHINES. Mechanical compositors. Briefly, typesetting machines are of three well-known makes: Intertype, Linotype and Monotype. Each comprises a keyboard similar to that of a typewriter, and in each case the operator depresses the keys according to his copy, releasing matrices, or brass moulds, which are assembled, either singly or in a line.

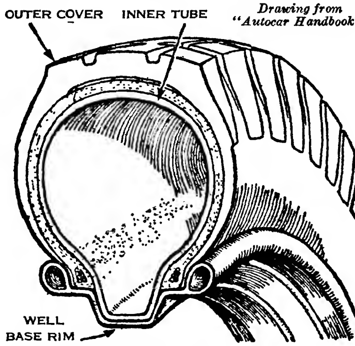
The Intertype and the Linotype cast and set lines of type known as slugs, whilst the Monotype casts and sets single types. In either case the used type can be melted down and the metal used again. See TYPESETTING.

TYRES. Pneumatic tyres of the well-base beaded type are used today on all vehicles. The outer cover, which is built-up of woven fabric and rubber, is formed to fit around the wheel rim as shown in the accompanying illustration. An air-tight rubber tube fits within the outer cover, or tyre, and this is inflated, through a valve, to the required pressure. To facilitate the removal of the outer cover the rim of the wheel is well-based.

To keep tyres in good condition they should be maintained at the recommended pressure. The treads should be periodically examined for cuts, and any small stones etc. which may be embedded should be removed. Oil on the covers should be wiped off as it has a deleterious effect on the rubber. If a tyre starts to deflate it is always advisable to look first at the valve to see if it be faulty. This can be done by turning the wheel until the valve is at the top and then immersing the valve in water; air bubbles will indicate a faulty valve.

To remove an outer cover deflate the tube and then push one edge of

Drawing from "Autocar Handbook"



Pneumatic tyre of the well-base type which is now used almost universally.

the outer cover into the well of the rim; the opposite side of the cover will then easily slip over the edge of the rim. To replace, one side of the tyre is first placed in the well-base and the other side pushed over the rim. When the cover is in position reinflate the inner tube, which will hold the sides of the cover tight against the sides of the rim.

Correct tracking of the wheels has a very important bearing on the life of a tyre. Tyres should never be allowed to wear down to the fabric but should be sent to be retreaded when the treads have worn smooth. Wheel-securing nuts should be frequently inspected to ensure that they are tight.

ULTIMATE STRESS. The maximum load supported by a test piece of metal in the tensile test at the moment of fracture, divided by the original area of the test piece. See TENSILE TEST.

ULTRAMARINE. A blue pigment formed as a compound of sodium silicate, aluminium silicate and sodium sulphides. It is manufactured on a large scale by heating together clay, sulphur, soda and coal and is used for washing blue, for colouring paper and in paints. In paints, however, there are limitations as to its satisfactory employment.

The pigment is supplied in two types: pale, having a greenish hue and suitable for mixing with yellow to make green; and deep, having a

violet hue and suitable for mixing with selected reds to give purple. It will withstand heat and the action of alkalis but is rapidly decomposed by weak acids and should not be mixed in paint with pigments containing lead or copper (white lead and emerald green).

Reduced in strength by the addition of a filler it forms the lime blue used exclusively for distemper painting.

ULTRA-SHORT WAVES. In radio a term generally applied to waves whose length is less than 10 metres.

UMBER. A natural, brown pigment, the colour of which is due entirely to compounds of iron and manganese. It is permanently opaque in water but is only moderately so in oil.

There are two varieties: *English* umber and *Turkey* umber. The former may be obtained as a dry, soft powder for distempering, or, with linseed oil, as a stiff paste.

In its raw state *English* umber is greenish-brown but when burnt it is a reddish-brown; it is used mainly in combination with other pigments for colour matching and to modify the more brilliant hues.

Turkey umber has two distinctive hues; as quarried it is a greenish-brown and in this state is termed *raw*; by calcination its hue is changed to a reddish-brown and its transparency improved. In both forms it is used for staining, modifying the colour of other pigments, and for graining (q.v.) and marbling (q.v.).

UNDERCARRIAGE. That part of an aeroplane which supports it when it is on the ground, and enables it to be manœuvred with ease when taking-off. It also absorbs shocks due to landing.

An under-carriage normally has three wheels, two to supply the main support and the third for stability. The main wheels are placed near the centre of gravity, the third may be situated either at the tail or at the nose.

In the past the tail position was most favoured, due partly to the direct replacement by a wheel of the tail skid fitted to supply braking effect on the ground before wheel brakes came into general use, and partly because the older and more lightly loaded type of aeroplane was landed with the engines throttled right back.

The nose wheel, or tricycle, undercarriage has come into favour in the last few years. It has the advantage that the landing need not be judged so accurately, for with a tail wheel, if the approach is made too fast the aeroplane will float for a considerable distance before settling on to the ground. With a nose wheel, however, it is possible to put the aeroplane on the ground appreciably above its stalling speed, because of the reduced angle of incidence with this arrangement when the aeroplane is at rest, brakes dealing with the extra speed.

The main undercarriage consists of three principal parts; the wheels with the brakes, the compression legs or shock absorbing units, to which the wheels are attached, and the supporting and bracing structure. This last is sometimes omitted, the compression legs being pure cantilevers. The most suitable method of operating the brakes is by compressed air, though on small aeroplanes hand operation through cables can be used quite satisfactorily.

The shock-absorbing medium in the compression legs can be either rubber, springs or air, the damping being obtained either by friction, or oil forced from one chamber to another through a small hole. The fore and aft bracing struts are called radius rods. On many designs of retractable undercarriage the jacks which carry out the retracting operations are attached to the radius rods, which break in the middle to enable the wheels to fold up into the wing or engine nacelle.

The nose and tail units are similar to the main units, but are on a smaller scale and with the brakes omitted; they are made so that they can castor, otherwise the aeroplane could not turn on the ground.

On most modern aeroplanes the main wheels, and sometimes the tail wheel, are made retractable, that is,

they fold up into the body of the aeroplane when it is in flight, so reducing the drag. The aeroplane can thus fly faster, or fly at the same speed with less power. See CASTORING.

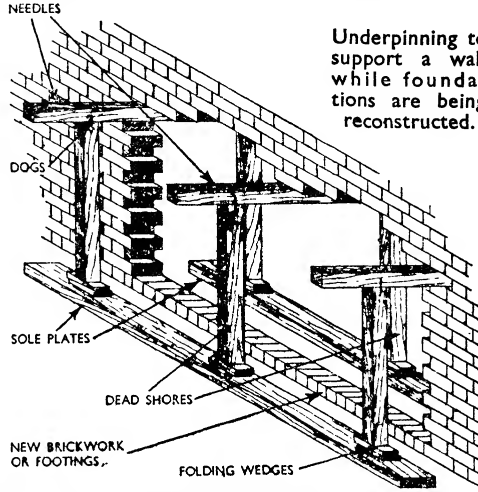
UNDERCLOAK (Building). A piece of sheet lead or other sheet metal which is weathered, or covered, by an overlapping sheet of similar material, used in covering wood rolls in roof work. The undercloak is first turned up over the wood roll and secured with nails, and the overcloak sheet is turned over the roll covering the joint of the undercloak to finish on the roof surface.

UNDERCOATING. The layers of paint between priming and finishing coats and the process of their application. Their function is to build up an impervious, substantial film, obscure the ground and provide a firm surface for the final coating. They may be obtained from the manufacturer of the particular finish to be used ready for application, or they can be made on the job from pigments ground in linseed oil, driers, refined linseed oil and turpentine or white spirit; excessive use of oil should be avoided, as this tends to form an unstable foundation for succeeding coats.

In colour, these coatings should approximate to that of the finish to be superimposed. The application of undercoating requires skilled and careful craftsmanship; careless brushwork in the preliminary stages cannot be obliterated by the final coating. Adequate stopping and filling is done upon the priming coat before the undercoatings are applied, each film being glasspapered and dusted.

UNDERPINNING. A term, used in the building trade, with two distinct meanings. In cases where the foundations to a wall are defective or are insufficient to take an increased load, concrete underpinning can be floated in below the decayed parts or existing footings, thus providing a new foundation and additional strength.

The term is also used in reference to the process of supporting a wall above the foundations, for the purpose of repairs or re-construction work. Dead shores, or vertical timber



Underpinning to support a wall while foundations are being reconstructed.

supports, on sleepers are used, as illustrated, a sleeper and shore on folding wedges being placed each side of the wall, with a needle across the tops. By this means, new foundations can be laid, new footings built, and the whole pinned-up to the existing wall above.

Underpinning is usually done in alternate sections, each section chosen being 3 or 4 ft. in length.

UNIPIVOT. A type of moving-coil instrument (q.v.) in which the movement is balanced on a single pivot.

UNIT POLE. An imaginary solitary magnetic north pole used in magnetic theory. It is defined in terms of force. A unit pole is repelled with a force of 1 dyne when it is 1 cm. from another unit pole.

UNIVERSAL JOINT. A device used to connect two shafts together so that one can rotate at an angle in relation to the other. Most universal joints used on modern road vehicles are of the metal type, consisting of two

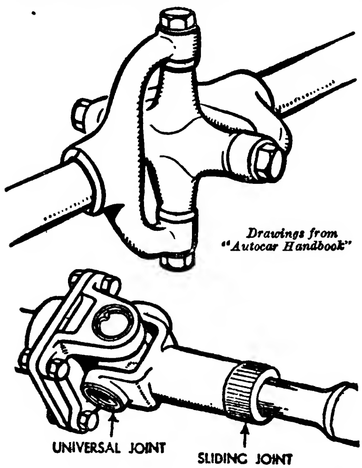


Fig. 1, top, shows simple universal joint and **Fig. 2,** below, universal in conjunction with sliding joint.

bearings pivoted on two pins at right-angles to each other. A simple universal joint is shown in Fig. 1, and Fig. 2 illustrates a universal incorporating a sliding joint. See TRANSMISSION (Auto. Engineering).

UNIVERSAL RECEIVER. A radio receiver designed to operate on either A.C. or D.C. supply mains without alteration or adjustment; sometimes called an A.C.—D.C. receiver. See RADIO RECEIVER.

URANIUM (U). Atomic no. 92; atomic wt. 238·07. A hard white metal, malleable and ductile, obtained from the mineral pitchblende; m.p. about 1850 deg. C. It is hexavalent, tetravalent and divalent, forming oxides UO_2 and UO_3.

It is the last of the elements in the periodic table, and is radioactive, slowly emitting α particles and β particles and being gradually transformed to ionium, radium and lead.

UREA ($OC(NE_2)_2$). Made industrially by synthesis (q.v.) from carbon dioxide, CO_2, and ammonia, NH_3. It is used in very large quantities in the manufacture of modern plastics (resins).

UREA-FORMALDEHYDE RESINS. These are formed by the condensation of urea with formaldehyde. They are colourless and transparent, and will take up many different colours. They can be loaded with cellulose fibre that gives them additional strength. Among the many urea-formaldehyde resins are Beetle ware, Pollopas, Plaskon and Scarab.

VALENCY. The combining power of an element with another; hydrogen, the simplest element, being taken as the unit. Thus, 1 atom of oxygen can combine with 2 atoms of hydrogen, and so oxygen is divalent, or bivalent. One boron atom can combine with 3 hydrogen atoms, and boron is trivalent; 1 carbon atom can combine with 4 hydrogen atoms, and carbon is tetravalent; 1 atom of phosphorus can combine with 5 atoms of hydogen, and phosphorus is pentavalent. Other elements are hexavalent, heptavalent, or octavalent.

The valency of an element is not always a fixed quantity; iron is sometimes trivalent and sometimes divalent; phosphorus is sometimes pentavalent and sometimes trivalent. The valency of an element depends on the number of external electrons in the atom. This number is never more than 8, and in hydrogen there is 1 external electron.

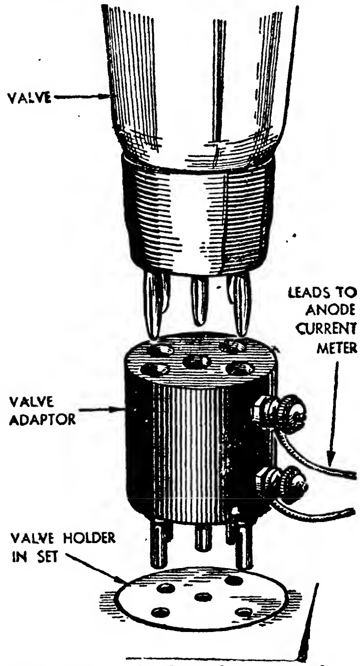
In some cases it is possible to draw a diagram showing the valency of the elements concerned by a few straight lines. In some cases, however, this procedure is not possible; e.g. benzene, C_6H_6, has a flat molecule in the shape of a regular hexagon with a CH group at each corner; here the combining power of the carbon atoms with each other is distributed throughout the benzene ring symmetrically, and cannot be accurately represented by lines attached to each carbon atom.

In liquids and solids the atoms are built up in space by packing them

closely together; this is accomplished in a manner that depends partly on the valency of each atom and partly on the size of the various atoms, for they differ greatly in size.

Valency is a simple property, and the word is essential in chemistry, but the complicated structure of solid bodies does not depend on valency alone. Carbon is undoubtedly a tetravalent element, but it exists in two different varieties, diamond and graphite, and these have quite distinct structures which are very accurately known. See ATOM, ELECTRON and ELEMENT.

VALVE ADAPTOR. A useful device by which a meter can be connected in the circuits of a radio valve in order to check operating conditions. The



Simple form of valve adaptor used to connect meter in radio valve circuit.

adaptor has pins on the underside and sockets above; it is plugged into the valve-holder and the valve inserted in the adaptor. In a simple type, the anode pin and sockets are connected to small terminals on the side of the adaptor as shown. In other types the valve sockets and meter connexion points are on a separate unit, joined to the adaptor by a multiway cable.

VALVE AMPLIFIER. A device employing thermionic valves and designed to amplify small alternating voltages. Amplifiers may be divided broadly into two main classes; one type for high (radio) frequency work, and the other for use with low (audio) frequencies. Most radio receivers employ both types.

The former amplifier serves to strengthen the received signal before it is demodulated, while the latter magnifies the intelligence before it is passed on to the loud-speaker or headphones. The last valve of an amplifying chain usually has to supply power to its load and is, therefore, chosen and operated to fulfil this requirement. It is, accordingly, called a power amplifier. See RADIO VALVE.

VALVE HOLDER. A multiple socket into which is plugged the base of a radio valve.

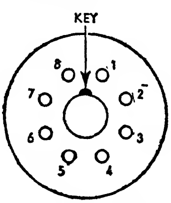
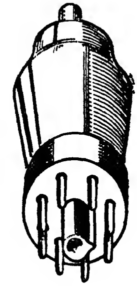


Fig. 1, above: plan of valve holder. **Fig. 2,** below: view of "octal" base.



Valve holders have been given a classification, which is generally recognized, according to the number of sockets with which they are provided, the spacing and number of such sockets corresponding to one of the standard valve bases.

One of the most widely used bases for small valves is the "international octal". In this, eight pins are equally spaced on a circle surrounding a central spigot which is provided with a key, so that incorrect insertion in the valve holder is impossible. Fig. 2 shows a perspective view of such a

base and Fig. 1 illustrates the spacing arrangements of a suitable holder.

VALVE, RADIO, see Radio Valve.

VALVE VOLTMETER. A device used for measuring voltages at audio and radio frequencies. It consists essentially of a thermionic-valve rectifier in which the rectified direct current gives an indication of the applied alternating voltage. It can be calibrated at low frequency and used up to very high frequencies without correction.

VALVES AND VALVE GEAR (Auto. Engineering). The valve mechanism of an internal-combustion engine is the means of controlling the entry and exit of gases into and out of the cylinders. Two systems of poppet valve gear are in use, side valve (S.V.) and overhead valve (O.H.V.). A side-valve engine, though very efficient, is not capable of developing the same power as an O.H.V. engine of similar size owing to the difference in formation of the combustion chamber.

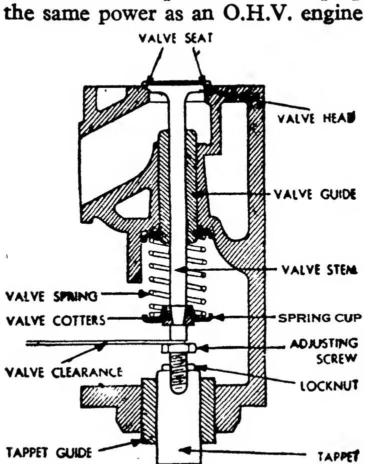


Fig. 1. Principal parts and general arrangement of side-valve gear.

A guide locates the valve and allows for its up-and-down movement during operation. The valve is ground into its seat (see Decarbonizing) and a gas-tight joint ensured by spring tension. A sectional view of a typical *side-valve* layout is shown in Fig. 1. Provision is made for valve adjustment on the tappet. A small clearance between the end of the valve stem and top of the tappet is necessary to allow for expansion with increases in temperature; this varies so widely with different types of engine that makers' instructions must always be followed. The foot of the tappet rests on the surface of the cam and as the latter rotates it applies the lifting effort to the valve against the pressure of the spring. As the cam lobe moves away from the tappet the spring forces the valve head down on its seating. On a side-valve engine the camshaft is situated directly under the valves and is parallel to the crankshaft.

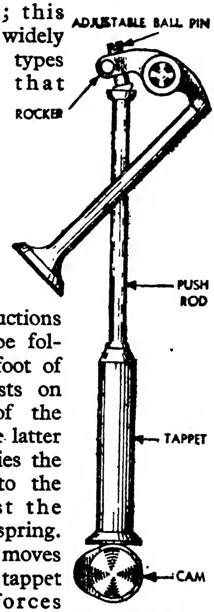


Fig. 2. How an overhead valve is operated by means of a cam, push rod and rocker arm.

Overhead Valves: there are two ways of operating the valves on O.H.V. engines. One method, shown in Fig. 2, is to mount the camshaft as in an S.V. engine. The valves, which are inverted, are depressed by a rocker arm pivoted at its centre. One end of the rocker arm is close to the valve stem; the other end rests on the top of a long push rod, located at its lower end in the tappet.

In the other method the camshaft is mounted on the cylinder head and the pushing effort of the cam is applied through a rocker or a plunger to the valve stem. Where push-rods are used, adjustment is effected by means of a ball-ended set-screw located in the end of the push rod, and held there

by a locking nut. On the overhead-camshaft type the rocker is generally wedge-shaped and pivots on an eccentric bush. As the bush is rotated clearance is varied by moving the rocker towards, or away from, the valve stem, the bush being finally locked in the desired position. Correct valve clearance is determined by inserting a feeler gauge between valve stem and rocker or tappet, as the case demands.

VANADIUM (V). Atomic no. 23; atomic wt. 50·95. A hard, silvery metal with a density of 6, m.p. 1729 deg. C.; principally used as a constituent of alloy steel, e.g. chromium-vanadium, manganese-vanadium and high-speed steels. It is contained in a few rather scarce minerals from which an iron-vanadium alloy can be prepared containing about 35 per cent of vanadium.

The maximum valency of vanadium is 5, and it forms the following oxides: V_2O_5, V_2O_4, V_2O_3, V_2O_2 and possibly V_2O. The addition of vanadium to steel distributes the carbon more uniformly, and vanadium steels are of considerable importance.

VANDYKE PROCESS. A printing process that is a familiar example of what has come to be known as a "reversal" process. It consisted of a modification in 1906 of previous "reversal" methods and has since been extensively improved upon in the modern deep-etch (q.v.) practice. It is used to produce diagrams, tracings, drawings and the like, which should be made on a translucent material, because the original is used as a light-controlling positive.

A lithographic zinc plate is grained finely, counter-etched, coated with a bichromated glue solution and dried away from light in a whirler. The copy is then placed in close contact with the sensitized plate, preferably in a printing frame, either face up or face down, depending on whether it is required for direct or offset printing, and exposed to arc lights. When the glue film is hardened sufficiently, the plate is developed under water to remove the unhardened portion, which has been protected from the light by the opaque parts of the copy.

To assist visibility during manipulation the coating is stained at this stage with a solution of methyl violet. The open parts of the plate are counter-etched with a suitable dilute-acid solution in preparation for the image-forming ink. Repair of the stencil or stopping-out of non-printing areas can be done with gum solution before inking in. A hard, lithographically active ink is reduced with benzol or turpentine, and applied to the open parts of the plate with a soft rag. It is useful to allow some time for the establishing of this ink. The removal of the stencil with a very dilute alkali or acid solution completes the operation.

Some advantages of this process are that (1) no camera is required and (2) size is limited only by that of the printing plate. A disadvantage is that only the copy size can be produced.

VAPOUR TRAILS (Aero. Engineering). There are two forms of vapour trail. One kind is formed by the steam in the engine exhaust freezing to form minute ice crystals. These trails appear just below the stratosphere at about 30,000 ft.; sometimes they are quite short, at others they are very persistent, becoming many miles in length.

The other kind of vapour trail is formed in the vortex (q.v.) shed by the wing tip, under certain conditions. In a vortex, there is a reduction in pressure, and, as a result, a lowering of the temperature; thus, if the air is near its dew point, condensation will occur, and a cloud of small water particles will be formed. The vortex has generally to be very strong before this happens, for example when an aeroplane is pulling out of a dive or making a tight turn.

VAR. Abbreviation for reactive volt-amperes. The product of voltage and the reactive component of current. Alternatively, the product of the current and the reactive component of the voltage. The result is the same.

VARIABLE CONDENSER. An electrical condenser whose capacitance

may, within fixed limits, be varied at will.

VARIABLE MU. A term applied to a radio valve whose mutual conductance depends upon the value of negative bias applied to its control grid. Such a valve is largely used in radio receivers as a radio-frequency amplifier, its properties being utilized for controlling volume and for automatic gain control.

VARNISHES. Transparent liquids for application to surfaces to improve their power of resistance to mechanical damage and disintegration by the action of natural forces.

Water varnishes, which are composed of gum soluble in water, are used to protect distemper work; they are best applied by spraying carefully on to the dry surface.

Spirit varnishes are composed of shellac (q.v.), either natural or bleached, supplemented by a soft resin dissolved in and diluted with alcohol; they may be marketed as polishes. They should be applied with a soft-haired brush in a warm, dry atmosphere; otherwise they are liable to become clouded, owing to the condensation of moisture upon their surface caused by the rapid evaporation of the alcohol.

Oil varnishes are made of refined linseed oil which has been heated, reinforced by the addition of driers and resins and, finally, diluted with turpentine or white spirit. Oil varnishes are divided into two types: hard, for use upon internal surfaces; and elastic, for use upon exteriors. They are also graded for colour: very pale, for use over delicate shades; pale, for use on darker colours and light-coloured graining and marbling; and what is simply called "varnish" for use upon darker graining and marbling and upon dark colours.

When dry, all these varnishes should give a uniform glossy finish, the hard varieties being surface-dry in not more than 8 hours and hard-dry in not more than 18 hours: the elastic varieties become surface-dry in 10 hours and hard-dry in not more than 24 hours. An extra-hard and non-softening type of oil varnish is made for use upon seats and floors. Flatting or rubbing oil varnish is specially made for undercoating; it becomes surface-dry in not more than 6 hours and in not more than 16 hours dries hard enough for cutting down to a dull finish with abrasive paper and water.

A surface intended to receive varnish is so prepared that none of the applied varnish is absorbed; it must be free from blemishes, evenly textured or granulated and without gloss. The material is applied evenly and regularly in a good flowing coat with compact bristle brushes, crossed and laid-off with firm strokes. No attempt need be made to obliterate the brush marks because the material itself will flow out into an even surface.

When two coats of varnish are specified, the first is a flatting or cutting-down varnish; after an interval of 24 hours this is cut-down with ground pumice powder, a felt pad and water, or with a fine abrasive paper and water, until the whole of the gloss is removed; it is then washed with clean water and leathered off. After another 24-hour interval the second coating, hard for inside or elastic for outside, may be applied.

Flat varnishes are used to give an evenly dull finish; they are composed of wax dissolved in turpentine and bound with a little oil varnish or gold-size. All types of varnish should be stored in a temperature of from 60 to 70 deg. F.; they also give the best results if applied in a dry atmosphere of similar temperature and free from draughts. See VARNISHING.

VARNISHING. The process of covering a surface with a protective coating, consisting of a solution of resinous gums in oil or spirits, which imparts a glossy finish to the surface. See VARNISHES.

In the printing trade, the term denotes the covering of a sheet of paper (usually printed) either entirely or selectively by a suitable varnish. The purpose may be entirely decorative or preservative, or both. Spirit

varnish is usually employed on paper, which is then passed on a slow-moving belt through a heated chamber to hasten the evaporation of the solvent.

Metal sheets, also, are varnished for similar reasons, but primarily for protection. A copal type of varnish is used and the sheets are stoved at a high temperature in specially constructed stoves or ovens.

V-CONNEXION. A method of connexion, sometimes used for electrical transformers etc., consisting of a delta connexion (q.v.) with one of the arms omitted. Synonym: Open-delta connexion.

V-CURVE. The relation between the excitation (q.v.) and line current in a synchronous electrical machine at constant load. The line current is minimum at the excitation which gives unity power factor and rises as the excitation is reduced or increased and the power factor falls. General shape is that of a shallow U or V.

VECTOR (Elec. Engineering). A line of fixed length rotating about one end at a fixed speed. This electrical vector is different from a mechanical or mathematical vector. Electrical vectors are used to depict the relative positions and sizes of currents and voltages. See ALTERNATING CURRENT.

VEGETABLE BLACK. A type of carbon obtained by burning vegetable matter with insufficient air; the light flocculent soot developed is collected in chambers through which the smoke is passed. It is sold as a dry, soft powder somewhat difficult to wet with either water or oil, and is used in small quantities by painters to correct the yellow hue of limewash and whiting distemper.

VEHICLE. The mobile portion of a paint or printing ink in which the pigment is ground or dispersed; it largely controls the working and drying properties of the paint or ink and its suitability for specific processes and purposes.

Drying vegetable oils have long been the chief sources of printing-ink vehicles. Linseed oil is the most important; others of varying degrees of usefulness are China wood, soya bean and Perilla oils. The use of synthetic resins has been widely extended during recent years, and these materials will be used increasingly as they are controlled to give certain specific results in conjunction with—but superior to those obtained alone by—linseed and similar oils.

VELOCITY MICROPHONE. Also known as ribbon microphone. See MICROPHONE.

VENTILATION. The supplying of air to the interior of a building, and an essential consideration in design and layout. An adequate supply of fresh air is necessary to preserve the building itself from dampness and deterioration.

There must be no "dead" spaces, i.e., spaces in which fresh air cannot circulate. Air bricks placed just above the level of the damp-proof course and surface concrete serve as vents for the supply of a current of fresh air under the floors in small buildings, or in cavity walls. In such types of house ordinary convection currents are sufficient to ensure a continuous flow of air. In larger buildings, however, air-conditioning plants with a system of ducts, and fans to assist the circulation, may be installed.

As regards public buildings, such as cinemas, theatres, churches etc., most local authorities insist on a certain standard of ventilation, usually about 1000 cubic feet of fresh air per person per hour. This ensures that the total volume of air contained by the building is completely changed within a given period, the number of changes per hour varying from two to three for assembly halls and similar places, to between six and ten for workshops and factories.

Thorough ventilation of wooden floors or timber structures is always necessary to prevent dry rot.

VENTING. In foundry work a method of increasing the permeability of sand, by making small channels in the cores or moulds through which the gases can escape.

Green-sand moulds as a rule require more venting than dry-sand

because of the large amount of steam produced by contact of the mould with the hot metal. Concave surfaces are more difficult than convex, because the volume of sand through which the gases have to pass is smaller. Similarly the drag presents more difficulties than the cope, and cores more than moulds.

In general, venting is accomplished by pushing a vent wire (q.v.) through the mould face, each passage so made either connecting-up with a large channel, such as a bed of cinders, or passing straight through to the bottom of the box. A wire $\frac{1}{8}$ or $\frac{3}{16}$ in. in diameter may be used, but the ends of the vents on the mould face must be closed and smoothed to prevent metal from entering. To aid the escape of gases from the drag, a number of channels should be made in the bed with a rammer handle. This is impossible with "bedded-in" moulds. In this case the mould is vented either by means of a curved vent wire passed through from the joint face, or by providing a bed of cinders 6 in. or so behind the mould face through which the gases can escape via a pipe to the atmosphere.

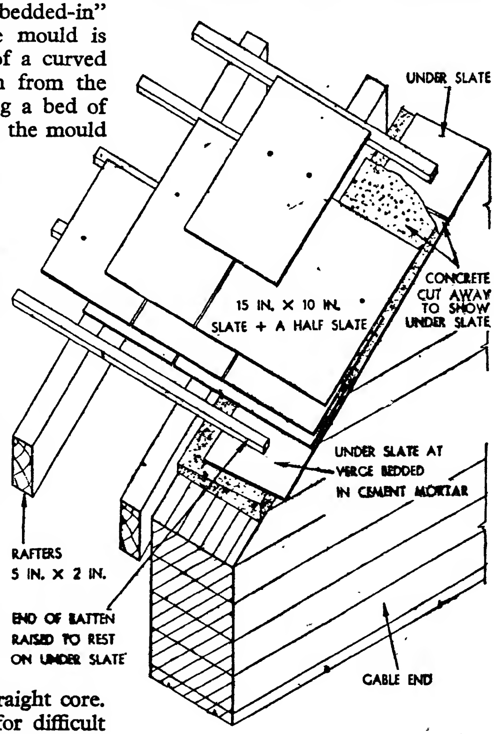
In the latter case, the same method of venting may be used as described previously, or large vents about $1\frac{1}{2}$ in. apart may be made before the last inch of facing is applied, the facing being needle-vented by means of a fine vent wire $\frac{1}{16}$ in. diameter passed through obliquely. This method is much used in large greensand moulds.

The methods used in venting cores differ somewhat from those for moulds. A central hole leading via the coreprint to a vent in the mould is all that is necessary for a small straight core. Black wax is much used for difficult cores. This substance melts when the core is dried and seeps into the sand, leaving open channels through the core. Straw rope is used for larger cores, especially in loam work. Cinders may be used to form channels in cores that are reinforced adequately with core irons.

VENT STACK. A term used in plumbing to denote that part of a soil pipe (q.v.) which stands above the soil inlet. Its purpose is to ensure the escape, above the level of windows, etc., of gases from the sewer.

VENT WIRE. A piece of steel rod enlarged at one end and fitted with a handle at the other, used in foundry work for making holes in the rammed sand of moulds, so that gases formed in the casting can escape. They are made in various sizes from $\frac{1}{16}$ to $\frac{3}{8}$ in.

VERGE. The portion of a pitched roof which projects over a gable wall. The construction demands an additional course of slates or tiles, which



Structural details of verge, showing how the additional slates are laid.

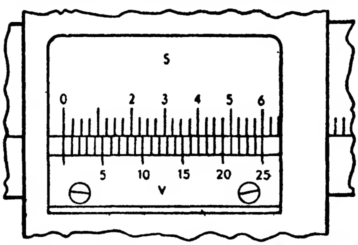
are laid on the wall beneath the battens. The space between the slates or tiles should be filled with cement mortar, as shown. See ROOFS.

VERMILION. A heavy, bright scarlet powder consisting solely of mercuric sulphide; it is a very opaque pigment insoluble in water, alkali or any single acid. Its use is somewhat restricted by its cost. Under ordinary conditions it is permanent; if, however, it is exposed to bright sunlight as a back-ground colour for glass fascias, it turns brown and eventually black owing to the automatic change in its atomic structure to black mercuric sulphide. See REDS.

VERMILIONETTES. A class of pigments, resembling vermilion in colour, composed of a dye fixed upon a mineral or metallic base. They are generally sold under proprietary names and were at one time subject to fading and bleeding; but most are now permanent, static, of good quality and opacity and may be used in any medium.

VERNIER. A scale for accurately making small measurements. In the accompanying diagrammatic sketch, the portion S carries the scale, whilst V is the vernier.

Suppose, for instance, that each subdivision of the scale S is equal to



Vernier, a small movable scale sliding along another scale, for making measurements of extreme accuracy.

$\frac{1}{40}$ in. and that the length of the vernier is arranged so as to equal 24 of these sub-divisions on S. The vernier itself, however, is divided into 25 parts. Then, if the extreme end lines on scale and vernier coincide, the first subdivision on vernier V will be shorter than the first subdivision on scale S by $\frac{1}{25}$ of $\frac{1}{40}$ = $\frac{1}{1000}$ in., or 0·001 in. Similarly the second subdivision on S by $\frac{2}{1000}$ in., and so on.

Now suppose V slid to the right so that its first subdivision coincided with the first one on scale S. The vernier has obviously been shifted 0·001 in. to the right. It must here be observed that if one pair of division marks is coincident, no two others will be so. By similar argument, if the right-hand boundary of the *sixth* subdivision on the vernier V coincides with the sixth on scale S, the distance through which the vernier has been moved to the right will be 0·006 in.

To take a vernier reading, therefore, observe (*a*) the number of complete inches, (*b*) the number of tenths and (*c*) the number of fortieths between zero reading on the vernier and zero on the scale. Then see which of the subdivisions on the vernier is coinciding with a division on the scale. For example if the movement of the vernier to the right is $3+\frac{3}{10}+\frac{7}{40}$ = $3+0·3+0·175$, or 3·475 in. and if the eighth division on the vernier coincides with the eighth on the scale S, then another 0·008 in. must be added to get the actual reading, which is thus $3·475+0·008$, or 3·483 in.

VERTICAL EDGING ROLLS. One or more sets of rolls imposed during the roughing stage of continuous-rolling of sheet metal to true the edges of the material, particularly in dimension. Any waviness accumulated could upset the truth of the coil in hot finishing, and would lead to excessive scrap in final shearing.

VIBRATION GALVANOMETER. An electrical indicating instrument for use in A.C. circuits. It often takes the form of a coil of wire carrying a mirror, in the field of a magnet. When the coil vibrates in sympathy with the alternating current passing through it, a beam of light reflected from the mirror appears as a band of light.

The mechanical design of the suspension is such that the movement is, or can be, tuned to the frequency of the A.C. In this way the effect

of the A.C. is magnified by mechanical resonance.

VIBRATOR. A reed-like vibrating interrupter which alternates the direction of current from a low-voltage secondary battery. In this manner it is possible to obtain a high voltage from the secondary of a special transformer whose stepped-up secondary voltage is rectified and used as an H.T. supply for radio and similar apparatus.

The special transformer has both its primary and secondary windings centre-tapped and the vibrating reed connects the battery first to one half of the primary and then, in the opposite direction, to the other half. The second voltage is determined by the transformer turns ratio. The reed vibrates at its mechanical resonant frequency, which is generally of the order of 100 cycles per second.

Non-synchronous vibrator power-supply systems incorporate a metal rectifier or valve, while *synchronous* types automatically reverse the transformer secondary connexions, thus providing rectification. Fig. 1 shows the circuit diagram of a non-synchronous vibrator power-supply system. The various R.F. chokes and condensers are necessary to reduce sparking at the contacts and to suppress radio interference. The output of the system is connected to a conventional smoothing filter. In Fig. 2 is shown a power-supply using a synchronous vibrator.

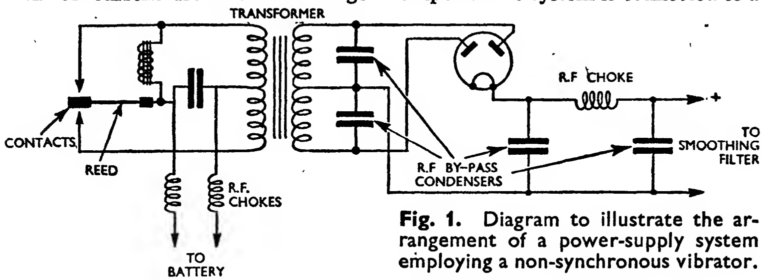


Fig. 1. Diagram to illustrate the arrangement of a power-supply system employing a non-synchronous vibrator.

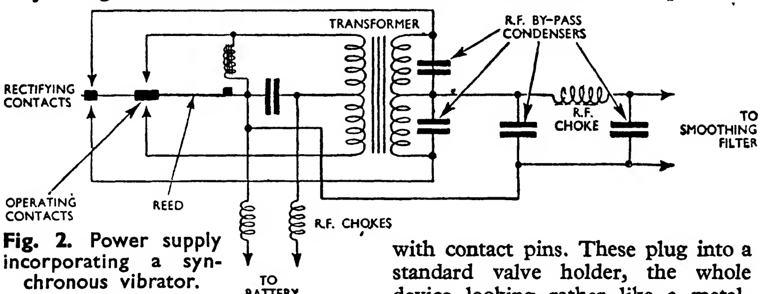


Fig. 2. Power supply incorporating a synchronous vibrator.

A vibrator is generally in a sealed metallic container which is provided with contact pins. These plug into a standard valve holder, the whole device looking rather like a metal-enclosed radio valve. Vibrators are occasionally used to convert D.C. mains supply to operate A.C. receivers.

VIDEO FREQUENCY. In television, a term applied to a voltage or current varying at a rate corresponding to the degrees of light and shade encountered in the scanning process. It is determined by the number of picture element pulses transmitted in unit time (generally one second).

VINEGAR. A dilute solution of acetic acid in water, usually containing from 4 to 10 per cent of acetic acid. In Great Britain it is made from malt which is fermented by yeast so as to convert the sugars to alcohol. The alcoholic liquor is then allowed to trickle through vats containing the ferment *Acetobacter*, and air is forced

to circulate through the vats. In this way the alcohol, C_2H_5OH, is oxidized to form acetic acid, $CH_3.COOH$.

VIRTUAL VALUE. Synonym for R.M.S. value (q.v.).

VISCOMETER, see VISCOSITY.

VISCOSE, see CELLULOSE.

VISCOSITY. The resistance of a liquid to fluid motion, a function of internal friction between molecules. The viscosity of lubricating oils is an important factor in mechanical engineering. In internal-combustion engines, for instance, the oil must withstand high pressures without being squeezed from the bearing surfaces under load, thereby allowing seizure.

It would seem, therefore, that the higher the viscosity the better. But, to obtain high mechanical efficiency in the engine, the minimum of friction is necessary, not only from the metal surfaces but from the oil itself, and, to satisfy this requirement, particularly when the engine is cold, the oil should have the minimum resistance to shearing and therefore a low viscosity. This viscosity resistance, however, is dependent upon the thickness and area of the oil film and is reduced considerably by increases in temperature.

An ideal lubricant for internal-combustion engines is, therefore, one in which there is the minimum change in viscosity with temperature change. Thus, to obtain the minimum oil resistance under normal running conditions, an increased viscosity must be tolerated when the engine is cold.

The use of mineral oils for engine lubrication is now almost universal in both road vehicles and aircraft. These oils contain additives to improve their viscosity when subjected to temperature since, in this respect, they would otherwise compare unfavourably with vegetable oils.

Viscosity is stated quantitatively as a reading in seconds (of time) and is measured at a standard temperature. The time is taken for a measured quantity of liquid to flow through a small orifice, and the apparatus for carrying out this test is called a viscometer.

Another example of the importance of viscosity is to be found, for instance, in sheet-metal work, where it has a considerable effect on the behaviour of enamels during smelting and firing on the ware, the movement of gas bubbles through softened enamel depending to a great extent upon it.

In firing of enamels especially, the movement of gas bubbles to the surface and the healing-up of the hole after the bubble has burst are retarded or accelerated according as the viscosity is high or low, with modifications from the effects of surface tension. Viscosity can be altered by variation in the proportions of batch ingredients. Increase in borax, alkalis or fluorspar will tend to lower viscosity, but it tends to rise with the increase of quartz, feldspar and clay, though such increase or decrease will be modified by local conditions.

While viscosity is a property of liquids, the general principles underlying the Redwood viscometer are applied in many enamelling plants to measuring the "flowability" of enamel slips. As the slip comprises a quantity of water solution with double its weight of suspended solids—and some clay—ability to flow is a complex of fluidity and plastic flow masked by suspended solids.

VITRAIN. A constituent of coal existing in thin, horizontal bands. It has a bright appearance, and sometimes shows evidence of plant structure.

VITREOUS ENAMELLING. A term loosely applied to the wet process of enamelling cast-iron as distinct from dry dusting, the latter being sometimes known as "bath enamelling". It is sometimes also understood to mean the enamelling of cast-iron, sheet steel and hollow-ware by the wet process. In a wider application it embraces both the above wet process and dry dusting, together with jewellery and art enamelling, and any process in which

enamel is fused on metal. See Adherence, Cover Coat, Frit, Ground Coat and Opacifier.

VITRIOLS, see Sulphate.

VOICE COIL, see Speech Coil.

VOLT. Symbol: V. The practical unit of electrical potential difference (q.v.). See Ohm's Law and Standard Cell.

VOLTAGE. Synonym for potential difference (q.v.).

VOLTAGE AMPLIFIER. A valve amplifier in which the voltage output, rather than the power output, underlies its design. See Radio Valve and Valve Amplifier.

VOLTAGE DROP. The potential difference (q.v.) between two points in an electrical circuit, provided that there is no source of e.m.f. between those points. See Ohm's Law.

VOLTAGE FEED-BACK, see Negative Feed-Back.

VOLTAGE REGULATOR. An electrical device either for varying a voltage or for keeping it constant. It may be automatic or manual.

VOLTAGE TRANSFORMER. An electrical transformer designed to reproduce, on its secondary side, a voltage proportional to, and in fixed phase relation with, the voltage applied to its primary. The secondary voltage is commonly 110V. when the normal voltage is applied to the primary. Synonym: Potential Transformer. See Transformer.

VOLTAIC CELL. Synonym for primary cell (q.v.).

VOLTAMETER. An electrical cell employed to measure a quantity of electricity in terms of the weight or volume of one of the chemical products, for example, the change in weight of a copper electrode. Synonym: Coulometer. See Electrolysis.

VOLT-AMPERE. Symbol: VA. The product of the voltage and current in an electrical circuit. In a D.C. circuit this is the power in watts, but in an A.C. circuit it is necessary to multiply the VA by the power factor to obtain watts. See Alternating Current and Power Factor.

VOLTMETER. An electrical instrument for measuring potential difference. See Moving-Coil Instrument and Moving-Iron Instrument.

VOLUME CONTROL. A device used in valve amplifiers and radio receivers to regulate the volume output at the loudspeaker or headphones. In radio receivers, the volume control is usually a potentiometer associated with either (*a*) the input to the audio frequency amplifier, or (*b*) the grid-bias circuit of an R.F. amplifier valve with "variable mu" characteristics.

VOLUTE. The part of an engine supercharger (q.v.) lying between the impeller and the induction manifold. In passing through the impeller, the air, or fuel-and-air mixture, receives energy in such a form as to increase its velocity; the function of the volute, and diffuser vanes when fitted, is to convert this velocity, or dynamic energy, into pressure, or potential energy, by expansion.

VORTEX. A rotating mass of fluid. A whirlwind and a whirlpool provide two examples from nature. Vortices are associated with form drag, for when the air passing round a body ceases to flow smoothly, i.e. when the streamlines break down, vortices are shed from its surface, and are left behind in the wake (q.v.). It requires energy to set the air in the vortices in motion, and this has to be supplied by pushing the body through the air, causing it to have drag. Vortices are also associated with induced drag (q.v.).

V.P.N. (Metallurgy). Vickers Pyramid Numeral. See Hardness.

VULCANITE. A hard black, elastic, non-plastic material also called ebonite, obtained by treating rubber with sulphur. Most rubber is mixed with a small quantity of sulphur up to about 4 per cent, and with about 5 per cent of zinc oxide, and the process gives it greater tensile strength and hardness and makes it a better insulator. It is further improved by the addition of carbon black. When rubber is incorporated with about 30 per cent to 32 per cent of sulphur it forms vulcanite, which is still harder and an even better insulator.

WAKE. Term used in aero. engineering to denote the region of turbulent, or disturbed, flow behind any part of an aeroplane in flight.

WALE ROTARY PRESS. A small precision-built high-speed letterpress printing machine which uses a flexible photo-engraved copperplate 0·012 in. in thickness, the non-printing parts being etched to a depth of about 0·004 in. below the printing surface. It is claimed that precision methods eliminate make-ready.

WALLBOARDS. Thin sheets of material used for covering large areas. The sheets may be of plaster, asbestos-cement, asbestos-wood, wood-fibre, strawboard, plywood etc., and are used for walls, ceilings, floors, form-work, furniture, panels and all types of joinery. Asbestos products are used for their fire-resisting properties and for external work.

Plasterboards consist of a gypsum core reinforced with straw etc., and faced on both sides with tough paper. These are used for walls and ceilings. *Wood-fibre* boards are the most varied. They include three different types: insulating, medium hard and hardboards, and are made from all kinds of wood fibre, from cane to any waste softwood, pulped into an emulsion.

The finished product depends upon the amount of heat and pressure applied in manufacture, although there are many different processes for preparing the pulp. The emulsion passes through rollers; these produce a ribbon-like board which is cut to the required size. Hardboards are produced by hot-plate presses, under a pressure up to 2500 tons. During the pressure various finishes may be applied to the surfaces. They are water-resisting and may be bent, by steaming, to almost any shape.

The thickness is about $\frac{1}{8}$ in. or $\frac{3}{16}$ in. and they can be sawn like ordinary wood. Insulating boards are up to $\frac{3}{4}$ in. thick. Wood-fibre boards vary in size, but usually they are up to 16 ft. by 4 ft., and if the length is decreased the width is increased.

WALL-PLATE. A piece of $4\frac{1}{2}$ in. × 3 in. timber, built into, or upon, a wall, to act as a bearing surface for the ends of floor joists, or roof rafters. Its function is to distribute the weight of the floor or roof. Whenever it is necessary to join two pieces of wall-plate, the timber should be cut to produce a halved or scarfed joint. See TEMPLATE.

WALL-TIE. Used in building cavity walls, as a means of tying the two walls together, thus preventing any tendency to buckling by wind pressure and superimposed loads. There are various forms of wall-ties, but the most effective appear to be those made of galvanized iron. The ties are twisted in crossing the cavity so that any moisture which may collect on the ties will drop clear of the inner wall surface. See CAVITY WALL.

WALNUT. A rich, dark-brown lustrous wood with darker streaks in the grain, very hard, heavy, strong and stable; extensively used in good-class joinery. Burred wood is extremely valuable for veneers, and is chiefly obtained from Mediterranean countries. American black walnut forms the bulk of supplies in Britain. See TIMBER.

WARPING. A distortion from natural state. In timber it is usually due to exposure to heat or moisture, while in metal castings which are thin and flat or very long, warping is caused by unequal rates of cooling at the top and bottom faces of the casting after solidification has occurred. In the latter, the mould, also, may offer more resistance to contraction in one part than another.

The effect is shown by the corners of flat plates or the ends of long castings turning up. To remove this effect the pattern may be curved in

the opposite direction—known as "cambering". Alternatively, sand may be removed from parts of the top half of the casting as soon as it is solid, in an attempt to equalize the rate of cooling on this surface.

Square or rectangular plates should be uncovered in the form of a diagonal cross; and long castings, by removing sand from the central portion only.

WASHING-UP. The removal of ink from the rollers and the inking section of a printing machine. Until recent years the operation was carried out by hand, rags or cotton waste being used with an inexpensive solvent, e.g. paraffin.

Modern rotary machines are, however, usually fitted with a mechanical washing-up device, the use of which, on large sizes and on two or more colour machines, saves time and avoids the necessity of frequent removal of rollers from the machine. The apparatus may be made as a unit which can be moved from one machine to another of the same type and size, but the modern method is to build the apparatus as an integral part of the machine.

In general design it consists of a flexible metal blade, so arranged that by a simple movement it scrapes at a suitable angle against a geared steel roller, cylinder or drum of the inking system, and deposits the ink-charged solvent into an underlying trough.

WASHITA STONE (Carpentry), see OILSTONE.

WASTE PIPE. A pipe for the discharge of waste water from sanitary appliances, not to be confused with the soil pipe, which, except in the one-pipe system, is for sewage water. Waste water comes from fittings such as sinks, lavatory basins and baths.

Waste pipes are of lead, cast-iron or copper, and no more than 2 in. in diameter, while branch pipes vary from 1¼ in. for a single lavatory wash-basin to 2 in. for the waste from the sink. Branch pipes should be as short as possible, and long lengths of horizontal, low-lying waste pipe should be avoided. The main waste pipe should discharge into the gulley trap (q.v.) by means of a back or side inlet, above the water seal; the practice of discharging waste and rain-water pipes into a gulley trap over a grating, so that the area around the grating becomes fouled, is not to be commended.

The use of hopperheads and light iron downpipes is also out of keeping with the principles of modern sanitation. Means of access to waste pipes for rodding or clearing purposes can be arranged in cast-iron pipe by fixing access junctions, and in lead and copper pipe by brass screw access caps. See DRAINAGE.

WATER (H_2O). The molecule of water consists of 1 atom of oxygen combined with 2 atoms of hydrogen. In steam or water-vapour the molecules are separate, and move about with a considerable velocity which increases as the temperature rises.

Water combines with many substances to form hydrates. Thus it combines with sulphuric acid and heat is evolved when sulphuric acid is poured into water. The common blue crystals of copper sulphate consist of a regular pattern of one molecule of copper sulphate, $CuSO_4$, and five molecules of water. The water in such crystals seems to consist of molecules loosely combined with the adjacent molecules.

Ordinary alum crystals contain 24 molecules of water loosely combined with 1 molecule of aluminium sulphate, $Al_2(SO_4)_3$, and 1 molecule of potassium sulphate, K_2SO_4. There is no evidence that the combination of these two sulphates and water exists except in the crystals. A solution of alum in water is very likely arranged on a different plan.

Water combined in a crystal of some compound such as copper sulphate or alum is often called water of crystallization.

WATER-BAR. The strip of metal inserted in grooves formed in the joint surfaces between a stone and a superimposed wood sill (q.v.). To seal the joint and render it water-tight, the metal strip is placed half

in the wood sill and half in the stone sill, and embedded in red lead.

WATER-COLOUR INK. A type of printing ink consisting of a dye or pigment mixed with water-colour "varnish", such as gum and glycerine. It is noted for brilliance of hue and great opacity. Transparent inks are also made, and are used in conjunction with linoleum, rubber and other non-metallic blocks; they are also used for gravure printing. Owing to the ready way in which water-based inks smear or damage on contact with water, an alcohol-resin content is frequently introduced; overprinting of solids then becomes less simple.

WATER GAS, see Fuels.

WATER GAUGE. A glass tube, usually vertical or inclined and protected by a metal shield connected at its upper end to the steam space of a boiler and at its lower end to the water space, the purpose being to indicate the height of the water level in the boiler. A typical water gauge is shown in Fig. 1.

The emergency cocks are for shutting off the steam and water in the boiler in the event of a fracture, whilst the lower cock is provided for blowing through the gauge to clear the passages. Water gauges usually

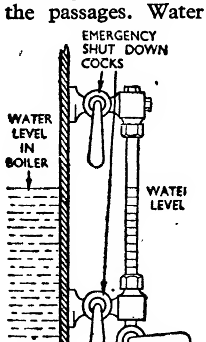
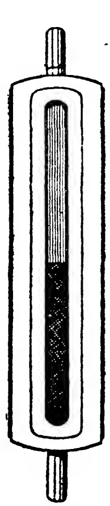


Fig. 1, above, shows in section a water gauge of normal type. **Fig. 2,** right, illustrates the more easily read reflex gauge.



carry a red line indicating the lowest water level commensurate with safety.

An improved form of the above is the type known as the *reflex* water gauge (Fig. 2). The plate glass of which the gauge consists is prismatic in form with the result that light striking the steam space, or that part above the water level, is reflected, giving the upper section of the gauge a silvery appearance.

Light striking the water space, however, is absorbed by the metallic back of the gauge so that the lower section, i.e. the part occupied by the water, appears jet black. The contrast, being considerable, enables the level to be easily determined, even from a distance.

WATER GILDING, see Gilding.

WATER GLASS, see Silicate of Soda.

WATER MAIN. The main pipe through which water is supplied to a town or buildings, usually laid in cast-iron sections under the road or pavement, and drilled, or tapped, as required for branch pipes to buildings. Branch pipes are generally of lead, and should be laid underground at a minimum depth of 2 ft. 6 in., with a fall back to the main, the connexion to which is by means of a stop ferrule (q.v.).

WATER SEAL. The quantity of water held in a trap (q.v.), measured in vertical distance from the throat to the crown of the trap. The deepest trap would be one having a seal of 3 in., but the depth of seal varies in different fittings, from $1\frac{1}{2}$ in. in waste-water fittings, such as baths and lavatory basins, 2 in. for water closets and slop sinks, $2\frac{1}{2}$ in. in intercepting traps, to the 3-in. trap mentioned, this last being fitted to waste-water appliances connected direct to a soil pipe or drain. Loss of water seal occurs owing to siphonic action or compression, due to the too-sudden discharge of waste. This must be prevented by an anti-siphonage (q.v.) system. Loss can also occur by means of capillary action, as when a hair or thread becomes lodged over the crown of a

trap, or owing to disuse and evaporation. See TRAP.

WATER-TUBE BOILER, see BOILER.

WATER-WASTE-PREVENTER, see FLUSHING CISTERN.

WATT. Symbol: W. The electrical unit of power. It is $\frac{1}{746}$ part of one horse-power and is a rate of working of one joule per second. See POWER.

WATT-HOUR. Symbol: Wh. The work done when a rate of working of one watt is maintained for one hour. Thus a 60 W. lamp consumes 60Wh. in one hour or 120Wh. in two hours. One unit is 1000 Wh.

WATTMETER. An electrical instrument for measuring power in watts. It may give a continuous indication of power or it may measure watt-hours, in which case it is an integrating wattmeter or watt-hour meter.

WAVEBAND. A term applied to a recognized section or division of the radio spectrum. Thus, for example the medium waveband is generally understood to include wavelengths between approximately 200 and 550 metres; similarly the 19-metre band refers to a relatively narrow allocation on the short waves for broadcast transmissions.

WAVEFORM, see OSCILLOGRAPH.

WAVEGUIDE. A hollow tube used for the transmission of electromagnetic waves. At very high frequencies, waveguides are an alternative to transmission lines. They are often of rectangular cross-section. One side of the rectangle, which must be a half-wavelength or multiple thereof, determines the transmission frequency. The other dimension is unimportant except in so far as it determines breakdown voltage. Circular waveguides are also in use.

WAVELENGTH. The length, or distance in space, between a given point on a wave and the corresponding point on a succeeding wave. In the case of a wave due to a sinusoidal force, it is also the distance travelled by the wave in a time corresponding to one cycle; i.e. in the periodic time. Radio waves travel with a velocity of approximately 300,000,000 metres per second and thus there is the relationship $\lambda = \frac{300,000,000}{f}$, where λ is wavelength in metres, and f the frequency in cycles per second.

The natural wavelength in metres of a tuned circuit is given by $\lambda = 1885\sqrt{LC}$ where L is the inductance in microhenrys and C the capacitance in microfarads.

WAVEMETER. A measuring device used in radio, comprising a resonant circuit usually tuned by means of a variable condenser. This condenser is usually calibrated so that the resonant frequency is indicated by its setting. Wavemeters are employed for checking the tuning of radio receivers and transmitters.

WAVETRAP. An obsolescent term for a filter comprising a tuned circuit connected to the aerial of a radio receiver to reduce the strength of a station which is causing interference. The most usual arrangement is a coil and condenser in parallel, interposed between the aerial itself and the aerial terminal of the receiver.

The condenser is adjusted to tune the coil to the interfering transmission; the circuit then "rejects" this frequency by presenting a high impedance, with the result that most of the unwanted voltage appears across the "trap" and is removed from the receiver input circuit.

Occasionally, an "acceptor" circuit of the coil and condenser in series is employed; at the resonant point, this arrangement offers minimum opposition to the interference. This type of trap, is therefore, connected across the aerial and earth terminals of the receiver, thus providing a low-impedance alternative path for the unwanted signal.

WAVE WINDING. A method of connecting electrical armature windings, particularly of D.C. machines. The shape of a coil is shown under the heading ARMATURE WINDING. The winding progresses round the armature in jumps of approximately a pole pitch until it reaches a position adjacent to its starting point. It then goes round again, and so on until all

slots are filled. There are thus only two parallel paths through the winding, no matter how many the poles. Compare this with LAP WINDING. See ARMATURE WINDING.

WEATHER-BOARDING. Boards tapering in thickness so that they will overlap easily and make a weather-proof joint. They are used mainly on timber-framed structures of the rustic or bungalow type, the thick edge of each board overlapping the thin, or feather-edge, of the one below it.

WEB-PRESS INKS. A type of ink in which the vehicle (q.v.) is usually mineral oil—resin oil may also be included—with a cheap lamp-black and possibly a small amount of toner. For better grades an amount of thin linseed-oil varnish may be used.

WELD DECAY, see INTERCRYSTALLINE CORROSION.

WELDING. The process of joining two metal pieces either by fusion of the pieces themselves, or by the fusion of another metal in the joint. These methods are further subdivided according to the means of supplying the necessary heat, and so on. See ARC WELDING, ATOMIC-HYDROGEN WELDING, AUTOGENOUS WELDING, OXY-ACETYLENE WELDING, RESISTANCE WELDING and SPOT WELDING.

WELT JOINT. A connexion made by plumbers in roof work for uniting sheets of lead. The joint is formed by turning up the edges of the sheets of lead against each other, and dressing them over flat on the roof surface in the form of a fold.

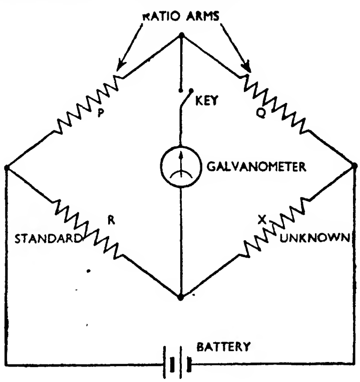
Its function is to render the connexion water-tight and at the same time permit the movement of the lead under varying temperatures. This type of joint is very frequently used for jointing sheets of lead when employed as the covering for exposed top surfaces of cornices etc. A welt joint should be made so that its position is parallel to the flow of water.

WET PRINTING-PROCESS INKS. Inks used on multi-colour machines (q.v.) where the several colours of the job follow in such rapid succession as to be practically simultaneously applied to the paper. This type of printing is made possible by decreasing the tack of each succeeding printing.

No sequence of colours can be dogmatically stipulated because so much depends on the peculiarities of each job; but the graded tackiness is of paramount importance. Otherwise, the character and ingredients of wet and dry printing inks are very similar.

Crystallization is impossible in wet printing, and the first colour should be caused to dry fairly quickly. Increasing use is being made of this process, and a high standard of work is produced by it.

WHEATSTONE BRIDGE. An electrical circuit used mainly for measurements of impedances and resistances. The layout is shown in the diagram, which refers to a D.C. version of the bridge. For A.C. work the battery is replaced by an A.C. source, while a vibration galvanometer or other indicator replaces the galvanometer. Various arrangements of impedances are then possible.



One way of using the Wheatstone bridge shown above is to set the ratio arms P and Q so that Q/P=1, 10, 100, 1/10, 1/100 or similar ratio.

WHEELING. In sheet-metal work a substitute for metal beating, particularly in the formation of double-curvature panels. The purpose of the operation is two-fold: (*a*) as a smoothing and finishing medium and (*b*)

by varying the pressure of the rolls, it is possible to make double-curvature forms from flat sheets.

The wheeling machine is a rigid, deep-throated structure, having two hardened-steel rolls which are manually controlled and operated. Weld finishing may also be accomplished in part by this machine, cold or hot working of the metal being accomplished in order to improve its mechanical properties or to relieve stress. The primary function of smoothing, however, is as usefully performed on weld metal as on ordinary flat sheet.

WHISTLERS. In foundry work, diminutive risers made by pushing a vent wire (q.v.) through the sand. They are used on parts of very thin section that project into the cope. See VENTING.

WHITE BRASS. Another name for nickel or German silver. See NICKEL SILVER.

WHITE CAST-IRON. Any iron containing such a silicon content that when made into castings its fracture is completely white. For light work a silicon content of 0·6 to 0·8 per cent is satisfactory, but in heavy work a still lower silicon content is desirable. Such irons are hard and brittle, being machined only with great difficulty.

White-iron is not very fluid and a high casting temperature is therefore required to obtain sound castings. Such irons are therefore employed chiefly for duties in which great resistance to abrasive action is required, as, for example, in sand or gravel pumps etc. White-iron castings may be made soft and ductile by a suitable annealing treatment. See MALLEABLE CAST-IRON.

WHITE DEAL, see FIR.

WHITE LEAD. A heavy white pigment also known as *Flake White*, which consists of hydroxy-carbonate of lead formed by the action of acetic acid vapour followed by that of carbonic acid vapour upon the metal lead.

It can be obtained by painters as a paste, ground into refined linseed oil, from which is made a paint of exceptional weather-resisting properties.

It is the only pigment which improves in quality by storage after grinding into linseed oil. As a dry powder, its sale is restricted to the operative who is himself going to use it as an ingredient in making white-lead filling for his own use. Regulations are also in force, applying to both employer and operative, for its storage as well as for the protection of the individual from poisoning.

Notwithstanding these restrictions it is still the best means of protecting external iron, timber and plaster surfaces from atmospheric disintegration. Paint made from white lead has good obscuring power, wears evenly and when aged is easily prepared for subsequent repainting.

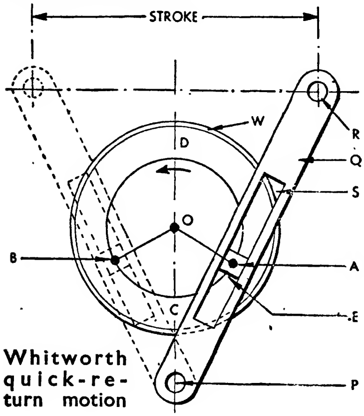
WHITE PINE. Extensively used for superior interior joinery, this wood, which comes from Canada, is more uniform in grain and texture than other pines, and is very easy to work. Also known as yellow pine, it is soft, light and very stable, and the small amount of resin is finely distributed.

WHITE SPIRIT. A clear colourless liquid obtained by distillation from petroleum; it is used extensively as a diluent for straight oil paint, but differs from turpentine in that it adds nothing to the resultant film. When used as a diluent for prefabricated materials, such as gloss and flat finishes, chilling may cause the binding medium to separate.

WHITING. White pigment used in glue-bound distemper painting.

WHITWORTH QUICK-RETURN MOTION. The best-known device for controlling the return or non-cutting stroke of the ram in a shaping machine, by which the ram on its idling stroke is made to return to the initial position for cutting in much less time than the cutting stroke occupies. The result is that the non-cutting proportion of the time needed for a job is much reduced, and therefore the productivity of the machine correspondingly increased.

The ram of the machine is oscillated by a vibrating arm, marked Q in the



Whitworth quick-return motion

accompanying diagram, attached at the upper end to the ram by a pin R and pivoted at the bottom end on another pin P. This arm is provided with a slot S, in which a block E is free to slide. The block E is also mounted on a crankpin A which is fixed to the rotating wheel W. When W is rotated by the motor or driving belt of the machine, the die block E causes the arm Q to oscillate from one extreme to the other.

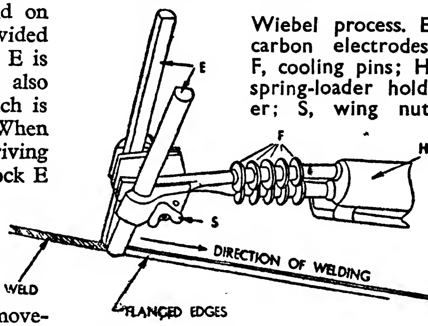
The rotational speed of W is unvarying, hence any *arc* on its surface is a measure of *time*. The movement of W around the arc ADB effects one complete stroke of the ram, the time taken being directly proportional to the length of the arc ADB. The return stroke of the ram is effected by the block E travelling back to A, around the arc BCA, which is likewise a measure of the time taken for the return stroke.

The ratio of the length of the arc ADB to the length of the arc BCA is thus the ratio of the cutting (or productive) time to the idling time; the nearer the pin P is to the centre O, the greater will this ratio be. For constructional reasons, however, the return stroke is usually made in two-thirds to one-half the time of the cutting stroke.

WIEBEL PROCESS. A Swiss patent, known in Switzerland under the trade name of F.E.S.A.; it is a fusion-welding process in which the heat is developed by passing a low-voltage electric current through the edges of the work via two carbon electrodes.

The edges of the metal are flanged, and these turned-up edges are placed in contact. They are straddled by two carbon rods of special form in a spring-loaded holder, and the electrodes are drawn along the edges, which melt to form the weld. Power is supplied from a transformer at 4 to 8 volts, and the current ranges from 50 to 250 amps, varying according to the thickness and composition of the metal welded.

The method is used chiefly for aluminium and its alloys up to 0·07 in. thick, but is employed also for



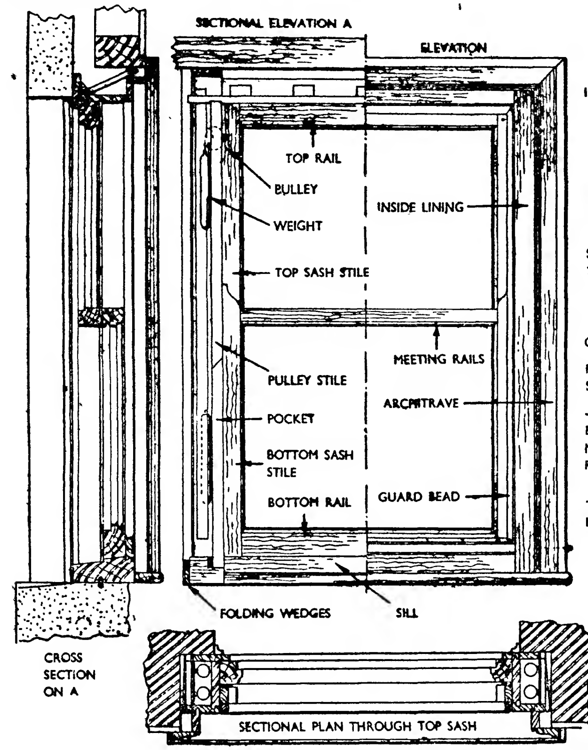
Wiebel process. E, carbon electrodes; F, cooling pins; H, spring-loader holder; S, wing nut.

lead and certain other non-ferrous metals. Reference to the accompanying diagram will make the principles and applications clear.

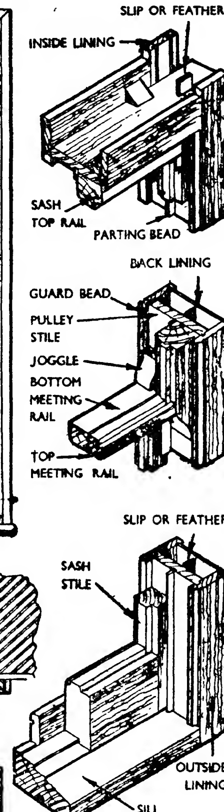
WIMSHURST MACHINE. A form of electrostatic generator.

WINDING. A collection of interconnected conductors forming an essential part of an electrical machine or other equipment, and not merely connecting two points together. See ARMATURE WINDING, LAP WINDING, WAVE WINDING and WIRING.

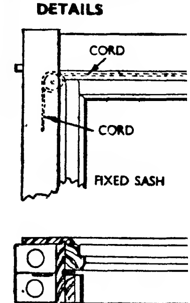
WINDOWS. The various types of window are known as fast sheets, sliding sashes, casements, pivoted sashes and Yorkshire lights, and the majority are of either wood or metal as illustrated. The primary object is to provide light, but ventilation and appearance are necessary considerations. For habitable rooms the area

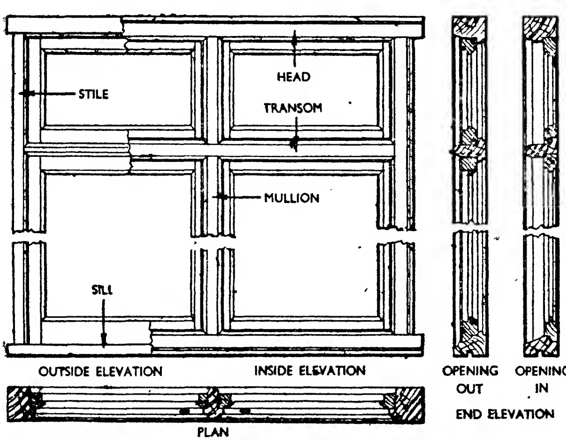


SASH-AND-FRAME WINDOW



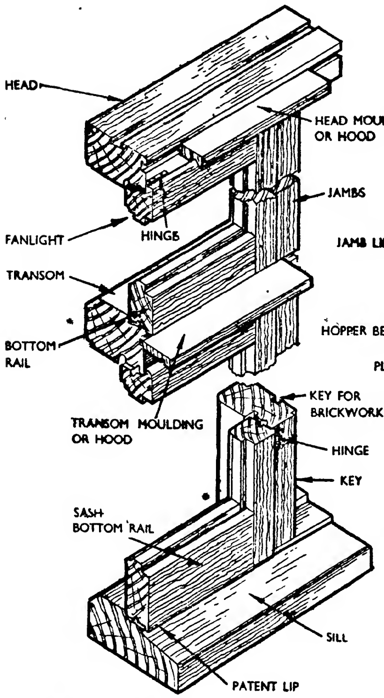
SASH AND FRAME DETAILS



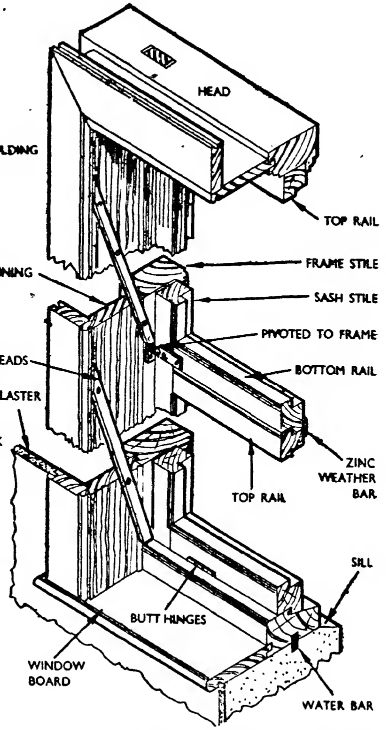


CASEMENT WINDOWS

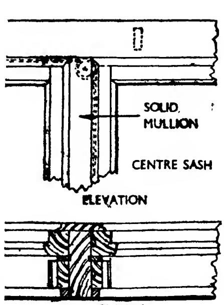
Some of the characteristic features of the more generally used types of window. A number of essential constructional details are illustrated, and these should



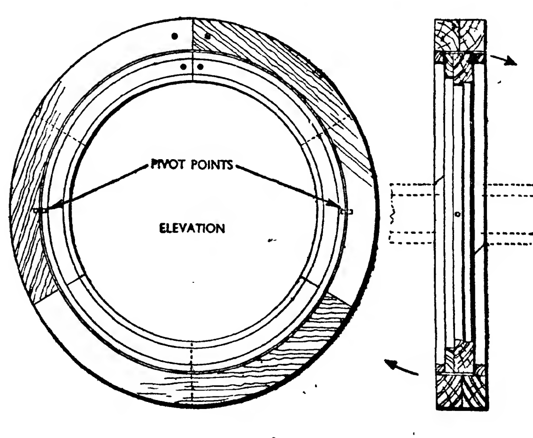
STORMPROOF WINDOW



HOPPER, OR HOSPITAL, WINDOW



SOLID MULLION



PIVOTED BULL'S EYE WINDOW

be studied in conjunction with the explanatory matter in the text. The material is usually wood, though metal has been extensively employed in recent years.

of the windows must be at least equal to one tenth of the floor area, and at least half of the window should open.

Windows are also named according to the number of lights, or divisions in the frame; according to the style of architecture, or to some special feature, as circle-on-circle etc. They are distinguished as bay, borrowed, bow, bull's eye, double, french, hopper, hospital, laylight, mullion, oriel, sash and frame, storm and venetian. Roof lights are distinguished as skylights, dormers and lantern lights. A fanlight is a glazed sash above a door. There are many registered types and combinations of the above.

SASH-AND-FRAME WINDOWS have been very popular in the past, but have been to some extent superseded by casement windows of either wood or metal. The sash-and-frame window consists of vertically sliding sashes balanced by iron or lead weights. The illustration shows both orthographic and isometric views to make the construction clear. A built-up box to hold the moving weights is the chief feature, and consists of a 1 or 1¼-in. pulley stile, and ¾-in. inner and outer linings.The sill and head are trenched for the pulley stiles, which are securely nailed in position.

The sill should be constructed of durable hardwood. The frame is carefully squared before the linings are nailed in position.

Guide and *parting* beads form recesses in which the sashes slide. It is usual to provide a thin slip to separate the weights, and to enclose the box with rough back linings to keep out mortar etc. The pulley stile is provided with a removable pocket so that the weight can be taken out to attach the cord. A strong cord is passed over the pulley and one end is attached to the weight, the other being nailed in a groove in the edge of the sash.

The difference between the sashes for this type of window and those for a casement window is in the meeting rails, as explained under JOINTS. Otherwise the joints are simple mortise-and-tenon, franked instead of haunched. Bars may be included to strengthen the sash, to reduce size of glass, or as an architectural feature.

MULLION WINDOWS are windows with more than two sashes, the mullion being the post or posts between the sashes. The simplest and most common type is the *Venetian* window, which has six sashes and two solid mullions.

The illustration at the bottom of page 632 shows details for passing the cords over the tops of the fixed side sashes. Only the centre sashes are hung, but they are considerably wider than the fixed sashes. Mullions may be solid or boxed. When, for instance, all the sashes are required to open, boxed mullions similar to the outer boxings are necessary.

If the window projects from the face of the wall and is supported from the ground, it is a *Bay* window. A similar window cantilevered out from the wall without ground support is an *Oriel* window. They are described as square, octagonal, or hexagonal, as the case may be.

When it is segmental or semi-circular it is a *Bow* window. The details are as previously described, except at the angles of the bays, and depend upon the importance of the work. They are simplified if the side lights are fixed. If they are behind brick or stone mullions, they are simply three separate frames, as the first example shows. A bow window presents difficulties in the circular work, except for casement windows, which are usually chords of the circle. All the foregoing windows are fixed in recesses in the brickwork.

STORM WINDOWS in the past were double windows, either sash and frame or casement, or a combination of both, and were intended to keep out sound as well as weather. However, the name is now frequently applied to mass-produced casement windows, provided with throatings, lips and hoods to keep out driving rain. An example of this type of

window is shown. The chief feature is the projecting lip to the casements.

This requires a special cranked hinge, like a box hinge. A plentiful supply of throatings and loose-fitting joints between casement and frame prevents capillarity. The weakness lies in the top rails, and these are protected by hoods, or head mouldings.

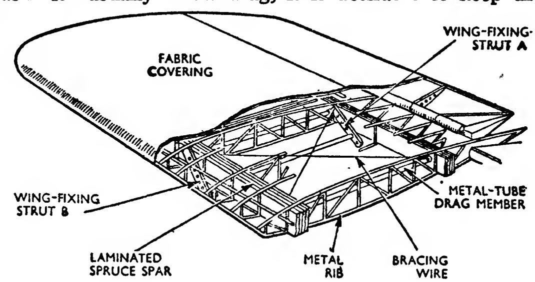
YORKSHIRE LIGHTS consist of a solid frame with a sash sliding horizontally. The sash is usually half the width of the frame, and the glass is fixed in the frame for the other half. Sometimes both halves are made to slide. No new details are entailed, except the arrangement for runners on the bottom rail to ease friction and to prevent wear.

PIVOTED SASHES are sashes which open by rotating on two pins, or pivots, in sockets, and this method is often adopted for small windows, hospital windows etc. When rebates are to be provided, the method of cutting the beads often presents difficulties. The illustration of a small circular window, or *Bull's-eye*, shows constructional details. The example shows both sash and frame built up in two thicknesses, or laminated. This makes a strong job because the grain is crossed and shrinkage does not cause so much distortion as in a solid frame.

HOSPITAL, OR HOPPER, WINDOWS are designed to provide ventilation without draughts. The reveals of the wall serve as hoppers, and the window consists of a frame with four independent horizontal sashes. The bottom sash is hinged to the sill, but the others are pivoted at the ends. When the sashes are open they rest on cleats screwed to the reveal linings. See LANTERN LIGHTS and ROOF LIGHT.

WING (Aero. Engineering). The wing receives the lift or sustaining force which keeps an aeroplane in the air, and carries two important control surfaces, the ailerons, which enable the aeroplane to be controlled and manœuvred in a lateral plane. It may also serve as a mounting for the undercarriage, the engines, flaps, slots etc., while it can accommodate internally the fuel tanks, guns, bombs etc., and, in very large aeroplanes, even passengers and freight.

In wing design there are two conflicting requirements. To obtain low drag, it is desirable to keep the thickness as small as possible, while to make the wing light in weight in relation to the load it has to carry, a thick wing is required to house deep-section spars. A compromise must be effected, and thickness chosen will depend on the performance required.



Cut-away drawing of a composite wing, fabric-covered, having the spars of wood and ribs of metal.

On ultra-high-speed aircraft the wing must be kept thin, even at the expense of large reduction in load-carrying capacity. The main load-carrying members are the spars; these run from one wing tip to the other, being in effect girders, sometimes pure cantilevers and sometimes supported by bracing struts. There may be one or two.

Spaced roughly at regular intervals along the spars are the ribs, light frameworks extending from the leading to the trailing edges. They are made to conform to the profile or aerofoil section, and so give the wing its external form when the skin is attached to them; they also transfer the lift loads from the skin to the spars. At one time it was the practice to cover the wings with

fabric; it still is the practice for small slow aeroplanes, but nowadays for two reasons a more solid covering is provided. First, fabric will not stand up to the loads imposed by high-wing loadings and high speeds, and, secondly, it is necessary to provide a high degree of torsional strength and stiffness, and a solid skin gives this.

Wings may be constructed from either wood (spruce and ply) or metal (duralumin and steel). Some are built in one piece, but normally there are two joints dividing the wing into three parts: two extension planes and a centre section. On a twin-engined aeroplane the centre section would run from just outboard of one engine nacelle to just outboard of the other (for a wing with no joints this portion would still be called the centre section).

On the smaller type of aeroplane, joints enable the wings to be folded back against the fuselage for ease of stowage. The breaking-down of the wings of large aeroplanes into three or more portions gives ease of handling and transportation.

The illustration shows a wing of composite construction, the spars being made of laminated spruce, and the ribs of metal, covered with fabric. This wing is for a small strutted monoplane, so a thick section to accommodate deep spars is not necessary. The struts are fixed to the spars at A and B, and lateral reinforcement of the spars will be noticed for a short distance on either side of these points to resist the bending moment due to the fixing. The wing is in three sections, the cabin roof forming the centre section, to which the outer section shown is attached by fixing lugs. The aileron, and position of the split flap inboard of it, are also clearly shown.

The wing of a high-speed cantilever monoplane, such as the Lockheed Lightning, is of all-metal construction. There are no ribs, and the stresses are taken by the tapering H-section spars and the stressed skin. The spars are jointed for removal of the outer section, and the wing is deep enough to house petrol tanks in the centre section.

WIRING (Auto. Engineering). Road-vehicle wiring is carried out by using one of two methods.

In the *single-wire* system, also called the earth-return system, the metal parts of the vehicle are used as a conductor. For example, if it is desired to connect up two head lamps, two side lamps and a tail lamp, using the single-wire method, they would be arranged as illustrated under the heading LIGHTING FOR MOTOR VEHICLES.

One terminal of the battery is connected to the frame of the vehicle, the other to a common switch-bar via an ammeter. When the switches are closed, current flows through the bulb filament and returns to the battery through the metal butt of the bulb, lamp shell and through whatever metal parts support the lamp. A diagram showing battery-and-coil ignition will be found under the heading BATTERY-AND-COIL IGNITION.

Two-wire systems do not use the chassis frame as a return, a second wire being employed. Cost of wiring is higher but risk of fire is greatly reduced. All public-service vehicles and those carrying inflammable fuels etc. have the two-wire system.

WIRING (Elec. Engineering). A collection of interconnected conductors forming part of a piece of electrical equipment or installation other than those covered by the term winding (q.v.). For example, the wiring of a house or of a switchboard.

WIRING HARNESS. The modern tendency in automobile engineering is to bind all the lengths of cable required for lighting, charging, auxiliaries, low tension, ignition etc., into one common harness, or loom, to simplify the wiring of a vehicle.

The cable ends are brought out of the loom at convenient points adjacent to the switchboard, control-box or other components.

To avoid confusion, the different cables are identified by a system of colours and with the aid of a colour key the various components are

connected from the wiring loom in their correct order.

WITHE. A division wall which separates one flue from another in a chimney stack. It is usually 4½ in. thick.

WOOD, see FUELS and TIMBER.

WOOD-FIBRE BOARDS, see WALLBOARDS.

WOOFER. A name given to a radio loudspeaker designed primarily for the reproduction of the bass and middle registers, the higher audio frequencies being dealt with by a "tweeter".

WORK FUNCTION, see EMISSION.

WORK-HARDENING(Metallurgy). The increased resistance to further deformation of a metal which has been strained by cold working (rolling, drawing etc). The hardness and tensile strength of cold-worked metal gradually increase, ductility being reduced.

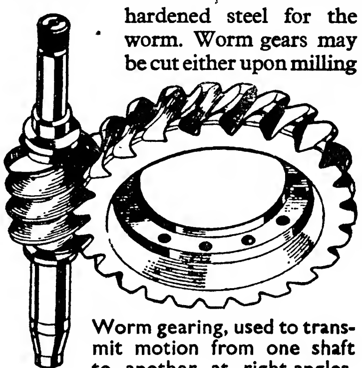
A possible explanation of work-hardening may be the greater resistance to slip caused by distortion of the slip planes. Alternatively, the crystals may be broken into fragments of varying orientation, the resistance to deformation thus becoming greater.

In the cold-rolling, pressing and drawing of sheet metal, work-hardening lowers ductility to such an extent that further deformation is impossible without annealing. This causes re-crystallization of the metal, which becomes ductile again; the number of inter-stage annealings required depends on the metal, and on the severity of the deforming operation.

WORM-AND-WORM-WHEEL DRIVE. A type of reduction gear used to drive two shafts at right-angles. In automobile engineering, for instance, a worm driven by the propeller shaft engages a worm-wheel which, in turn, rotates the axle shafts. The worm may be mounted above or below the worm wheel. The efficiency of the unit depends largely on the materials used in its construction, and upon adequate lubrication.

WORM GEARING. A useful method of transmitting motion from one shaft to another when, as illustrated, the two are at right-angles but not in the same plane. It gives a steady transmission of power at high efficiency and is also invaluable when a considerable decrease in velocity, e.g. to one-fiftieth of the rotational speed of the worm, is desired. It also enables a high mechanical advantage to be obtained.

Phosphor bronze is customarily used for the worm-wheel and hardened steel for the worm. Worm gears may be cut either upon milling



Worm gearing, used to transmit motion from one shaft to another at right-angles.

or upon gear-hobbing machines, and the required profile is produced by: (a) adopting a straight hob and a radial feeding movement between gear and blank; (b) traversing a "fly-cutter" in a tangential direction with regard to the woven gear blank; or (c) imparting a tangential traversing or feeding movement to a tapering hob.

The last method is preferred for large gears with comparatively wide faces, as well as for gears intended for use with worms provided with steep helix angles.

The flycutter method of working is rather slow, but is more accurate than the use of a straight hob; moreover, the cutter is much cheaper and simpler than a hob. On the worms themselves, the thread may be cut either on a gear-hobbing machine or on a thread-cutting lathe employing a single-point tool.

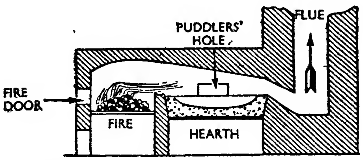
Another method sometimes adopted is to use a thread-milling machine and disk type of cutter. See DIFFERENTIAL

GEAR and WORM-AND-WORM-WHEEL DRIVE.

WRIST PIN, see CONNECTING ROD.

WROUGHT-IRON. A variety of iron made by refining pig iron in a puddling furnace as illustrated.

The charge of pig iron is melted and is then mixed with the slag



Sectional view of arrangement of puddling furnace for refining pig iron.

produced in melting-down and with oxidizing materials, such as hematite iron-ore and mill scale, added in suitable proportions. After thorough mixing, the temperature of the charge is raised and a violent reaction occurs.

The carbon, present in the original pig iron, burns to form carbon monoxide, which, bubbling through the slag, gives rise to the appearance of boiling. At the same time, any silicon present is oxidized and passes into the slag. The elimination of impurities causes the melting point of the charge to rise progressively.

As the maximum temperature obtainable in a puddling furnace is insufficient to melt pure iron, the melt finally assumes a pasty form consisting of nearly pure iron mixed with considerable quantities of slag. This mass is worked very thoroughly by the puddler to ensure completion of the reaction throughout, to cause the particles of iron to agglomerate and to squeeze out slag.

Finally, the charge is broken-up into a number of balls, each weighing about 60 to 80 lbs. Each ball is removed in turn from the furnace and is then passed under a hammer or squeezer, when much of the residual slag is expressed, the product being known as puddled bar. By cutting puddled bar into lengths, piling, reheating and rerolling, merchant bar of superior quality is obtained.

Owing to the method of manufacture, wrought-iron invariably contains considerable quantities of slag in the form of irregularly shaped particles which become elongated into threads during the rolling operations, so giving rise to the fibrous fracture associated with wrought-iron. Good quality wrought-iron is soft and ductile, having a tensile strength of 20 to 25 tons per sq. in. It is generally worked hot and may be welded readily under the hammer. It is used for making chains, hooks and ornamental gates.

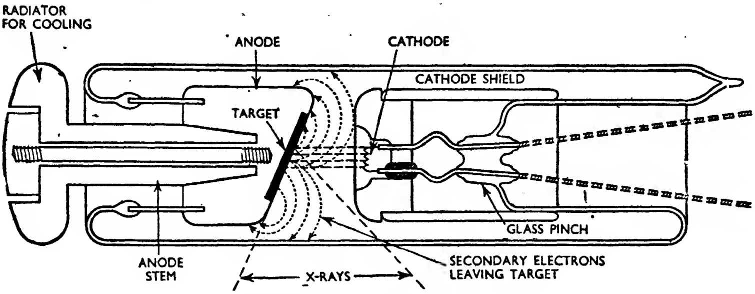
XENON (Xe). Atomic no. 54; atomic wt. 131·3. One of the inert, rare gases contained in the atmosphere, in which it is present to the extent of 1 part in 170 millions by volume. It has a density of 3·08 at its boiling-point. It melts at −140 deg. C., boils at −107 deg. C. and forms no compounds.

X-RAYS. When an electric current is passed through a vacuum tube containing a small quantity of a gas, the contents of the tube glow except in a few places, one of which is near the cathode, or negative terminal, from which the cathode rays are emitted. When these rays are made to strike a solid body they set up a new sort of radiation that can pass through flesh, wood and thin metallic foils and will act upon a photographic film. This radiation consists of X-rays with a much shorter wavelength than the ultra-violet rays in the solar spectrum.

A diagrammatic view of an X-ray tube is shown on the next page. A tungsten filament, or cathode, is electrically heated and maintained at a high negative voltage of some tens of thousands of volts. Electrons are given off and are directed on to the target, X-rays being emitted.

The X-rays have wavelengths of about ·03 to 1000 Ångström Units

(Å.U.). The ultra-violet rays have wavelengths of about 130 to 3900 Å.U.; the rays at the red end of the visible spectrum have a wavelength of about 7000 Å.U. By suitable instruments the effect of the X-rays on a photographic plate may be recorded and the result is found to consist of a number of lines. The simpler elements have simpler X-ray spectra than the heavier elements.



DIAGRAMMATIC VIEW OF X-RAY TUBE

Arrangement of components in the tube, showing the electrodes and path of the X-rays produced by impact of the electrons at high velocity on the metal target.

XYLONITE, see CELLULOSE.

YAWING. The rotation of an aeroplane around its yawing axis. See AXIS.

YELLOW PINE, see WHITE PINE.

YELLOWS. Ochre, sienna, lead and zinc chromes, Dutch pink and the yellow lakes are pigments used mainly for imparting colour to white pigments; in combination with reds they produce orange hues and, in combination with blues, they give greens. They may all be obtained as dry, soft powders or as pastes ground in water, turpentine or refined linseed oil.

YIELD POINT. An important result in a tensile test on steel, indicating the stress at which plastic deformation takes place under constant or reduced load. As the load increases, deformation is at first elastic and then plastic or permanent. Soon after the elastic limit is passed, there is a sudden extension or yielding, a very small increase in the load causing a relatively large extension.

In a lever testing machine, sudden ...ping of the beam indicates the ... ...h also gives rise to a discontinuity in the stress-strain curve.

The actual yield-point value in tons per square inch is given by

$$\frac{\text{Yield load (tons)}}{\text{Original cross-sectional area (sq. in.).}}$$

The yield point gives a useful indication of the behaviour of steel under a tensile stress

Stretcher-strain marks in pressed and drawn steel sheet are due to yielding in localized regions. The yield point can be eliminated by slightly cold working (temper rolling) the sheet before forming. Pressing should, however, be carried out as quickly as possible, since the effect of rolling rapidly wears off. See ELONGATION, NECKING and TENSILE TEST.

"Y" METAL. An alloy sponsored by the British Aluminium Company; it was one of the pioneer developments in the direction of securing an aluminium alloy which would be easily machinable and, at the same time, possess good mechanical properties.

The excellent machining qualities are obtained by the addition of copper, whilst nickel improves the mechanical

strength. The percentage composition is approximately: copper, 4; nickel, 2; magnesium, 1½; remainder aluminium. For alloys of this type, the degree of hardness (95-105 Brinell) is high, indicating resistance to wear. The principal drawbacks, as compared with more modern alloys (e.g. "Alloy 226" of the British Aluminium Company), are a comparatively low tensile strength and a tendency towards porosity when cast.

Sand-cast specimens after heat treatment give a tensile strength of 14 to 15 tons per sq. in. on test, with an elongation up to 1 per cent on a 2-in. gauge length. For chill-cast heat-treated specimens, the corresponding figures are: tensile strength, 18 to 20 tons per sq. in.; elongation, 2 to 4 per cent.

YOKE. A portion of a magnetic circuit which serves to complete the circuit by magnetically connecting essential parts.

YORKSHIRE LIGHT, see WINDOWS.

YTTERBIUM (Yb). Atomic no. 70; atomic wt. 173·04. One of the rare-earth elements; it has not been isolated. It is trivalent and divalent, and its compounds are unimportant.

YTTRIUM (Y). Atomic no. 39; atomic wt. 88·92. An element contained in monazite and certain rare minerals. It is trivalent and divalent.

ZEOLITES. Aluminium-silicates of sodium or potassium in which these elements are easily replaced by others, such as calcium. They occur naturally, and can also be made artificially by heating clay with sand and sodium carbonate. The formula is roughly $Na_2Al_2Si_2O_8.6H_2O$.

If hard water containing calcium compounds is allowed to flow through a thickness of zeolite, the calcium is taken up by the zeolite and sodium given in exchange; the water is thus rendered soft. When the zeolite is charged with calcium, sea-water or some other solution of common salt is run through it, and the zeolite gives up its calciun and takes sodium in exchange, so that it can be used as a softening agent again and again.

ZIG-ZAG CONNEXION. A method of interconnecting the electrical windings of a three-phase transformer. Synonyms: Inter-connected star connexion; Interstar connexion.

ZINC (Zn). Atomic no. 30; atomic wt. 65·38. A whitish metal of which the principal source is zinc sulphide, ZnS (zinc blende). Pure zinc at ordinary temperatures is hard and brittle, density 7·15 m.p. 419 deg. C.; b.p. 907 deg. C.

It is used in large quantities as a protective covering for iron (see GALVANIZING). It readily tarnishes in air, forming a basic carbonate.

It is divalent, forming many important compounds, such as zinc chloride, $ZnCl_2$, largely used in the textile industry and in medicine, zinc oxide, ZnO, an important pigment also used in medicine, lithopone, made by calcining a mixed precipitate of barium sulphate, $BaSO_4$, and zinc sulphide, ZnS. Both zinc oxide and lithopone are known as zinc white.

ZINC WHITE. A bulky, fine white powder (zinc oxide) having a slightly bluish hue. It is formed by heating metallic zinc to vaporization in contact with air. It is insoluble in water, alcohol or turpentine, but dissolves in weak acids, and is also soluble in ammonia and alkali mixtures. Its main use is for the pigmentation of enamels and the fabrication of paints, known as Chinese White, for internal use. See LITHOPONE.

ZIRCONIUM (Zr). Atomic no. 40; atomic wt. 90·6. A whitish crystalline metal, m.p. about 1600 deg. to 1650 deg. C.

Zirconium forms two oxides, the sesquioxide, Zr_2O_3, and the dioxide, ZrO_2 (zirconia); the latter has been used for refractory crucibles. Good specimens of the silicate, $ZrSiO_4$, a common mineral, ar wavelength gem
ngström Units

Odham's Practical and technical encyclopaedia